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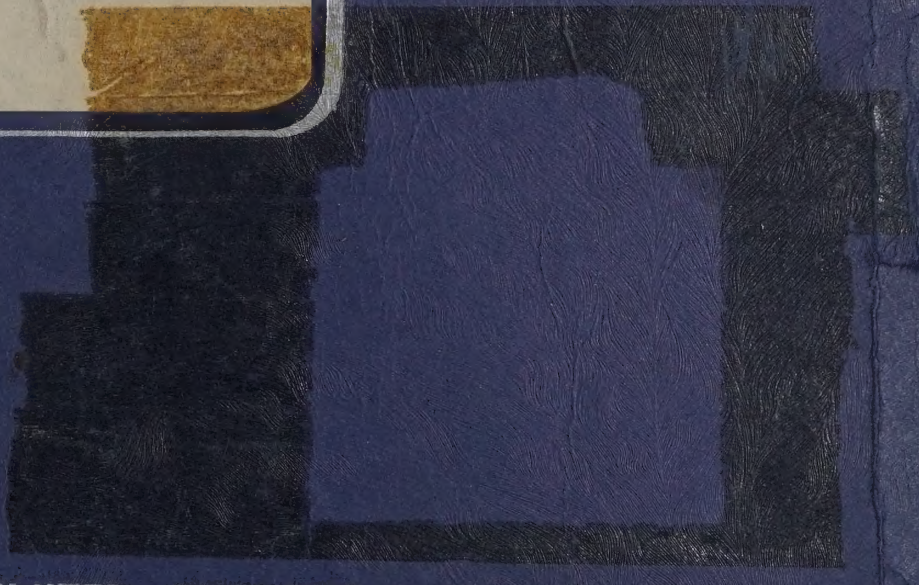
Operating Instructions

1/4% UNIVERSAL BRIDGE.
TYPE. TF. 1313



MARCONI INSTRUMENTS LIMITED, ENGLAND

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OPERATING INSTRUCTIONS

No. EB 1313

for

1/4% UNIVERSAL BRIDGE TYPE TF 1313

AMENDMENTS, if any, are included at the end of the handbook.

1 INTRODUCTION

TF 1313 is a general-purpose impedance bridge with quarter per cent measurement accuracy over a wide range of inductance, capacitance, and resistance. It offers exceptional discrimination and resettability, wide-range loss balancing, and facilities for using an external oscillator and detector.

The single direct-reading dial used for L, C, and R measurements has coarse and fine concentric controls; the coarse one moves in 1% steps and the fine gives continuously variable interpolation between steps. Its meter gives a clear indication of the direction of the balance point even when far off-balance, bringing speed and simplicity to measurements of completely unknown components. An external audio oscillator can be plugged in where L and C measurements are required at frequencies other than the internal 1 and 10 kc/s; and the detector output is available externally to allow an oscilloscope or headphones to be used for balance indication.

This bridge can be used for precision evaluation of resistance, capacitance and inductance, for measuring dissipation factor of capacitors and Q of inductors, and for quickly identifying unknown components. Measurements on high-loss components are made easier by the low-Q range of the loss balance control and the relative independence between the adjustment of the main and loss balance controls. Its high discrimination and resettability make it particularly suitable for comparative measurements such as checking the difference between an unknown and a standard component. Measurements on inductors carrying a d. c. current can be made by using Adaptor Type TM 6113, which is available as an optional accessory.

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DRAWINGS	Ref. No.
SUPPLY VOLTAGE PLUG SETTINGS	Following p 27
FUNCTION DIAGRAM	XD 35166
CHARTS OF TEST TERMINAL VOLTAGES AT BALANCE	XD 30557
CIRCUIT DIAGRAMS ..... (3 sheets)..	XD 32020
D.C. CHOKE ADAPTOR CIRCUIT DIAGRAM	XC 31308

DATA SUMMARY

for

1/4% Universal Bridge Type TF 1313

Serial Nos. JA 642/001 and above

MEASUREMENT RANGES

Inductance:	0.1 μH to 110 henrys in 7 decades; at 1 and 10 kc/s.
Capacitance:	0.1 μμF to 110 μF in 7 decades; at 1 and 10 kc/s.
Resistance:	3 mΩ to 110 MΩ in 8 decades; at d.c.
Q:	0.1 to 31 at 1 kc/s; 1 to 310 at 10 kc/s.
D (tan δ):	0.001 to 0.031 at 1 kc/s; 0.01 to 0.31 at 10 kc/s.
	Since Q = 1/D, scales combine to give extended Q coverage up to 1,000 and D up to 10.

ACCURACY (at 1 kc/s*)

Inductance :	±0.25%±0.01% of range full-scale.
Capacitance:	±0.25% ±0.01% of range full-scale.
Resistance (at d.c.):	±0.25% ±0.01% of range full-scale.
Q:	±7% ±0.1 for Q greater than 0.5*.
D:	±7% ±0.0015.
Oscillator Frequency:	±2½%.

* At higher frequencies and/or low Q the accuracy figures include an additional term $\pm F(0.01 \pm \frac{0.1}{Q})\%$ where F = frequency in kc/s.

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RESIDUALS (approximate):	Inductance :	0.05 μH.
	Capacitance :	0.08 μμF.
	Resistance :	0.001 ohm.

BRIDGE ENERGIZING SOURCE

L and C:	Internal 1- and 10-kc/s oscillator; fixed output level between 250 and 750 mV. External audio oscillator may be used instead.
R:	Internal d.c. supply, nominally 4 volts; nominally 22 volts on highest range.

POWER SUPPLY: 200 to 250 volts and 100 to 130 volts, 40 to 60 c/s, 25 watts.

DIMENSIONS & WEIGHT:	Height	Width	Depth	Weight
	$11\frac{1}{2}$ in (30 cm)	$19\frac{1}{2}$ in (50 cm)	10 in (26 cm)	27 lb (12.5 kg)

SCHEDULE OF PARTS SUPPLIED

The complete equipment comprises the following items :-

1. One 1/4% Universal Bridge, Type TF 1313, complete with valves, etc., as under :-

Valves :	One:	Type EF86 (6267), Pentode.
	One:	Type 6X4 (EZ90), Full-Wave Rectifier.
	One:	Type 12AT7 (ECC81), Double Triode.
	One:	Type 12AX7 (ECC83), Double Triode.
Semi-conductors:	One:	Type OA73, Germanium Diode.
Lamp:	One:	Cinch Type 79/619, Amber, Pilot Lamp.

2. Two Telephone Plugs, Type P40; for external oscillator and detector jacks.

3. One Instruction Book No. EB 1313.

ACCESSORIES AVAILABLE

D.C. Choke Adaptor, Type TM 6113; enables d.c. currents up to 200 mA from an external supply to be passed through inductors under test at 1 kc/s in the range 100 mH to 100 henrys; fitted with test leads for attaching to bridge terminals. Errors introduced by the adaptor do not generally exceed 3% and may be eliminated by simple substitution methods.

2 OPERATION

2.1 INSTALLATION

The 1/4% Universal Bridge is normally dispatched with its valves in position and with its mains input circuit adjusted ready for immediate use on 240 volts within the supply frequency range 40 to 60 c/s. If required, the instrument may be adjusted for operation from other supplies within the ranges 100 to 130 and 200 to 250 volts. To check or alter the tappings on the mains transformer, refer to Section 4.3.

2.2 PRELIMINARIES

Having checked that the instrument is correctly adjusted to suit the particular supply voltage to which it will be connected, proceed as follows :-

(1) If necessary, mechanically adjust the meter to indicate zero.

(2) Connect the mains lead to the supply socket. The lead is normally stowed in the left-hand case-handle recess.

(3) Put the SUPPLY switch up; the red pilot light should now glow.

(4) Before using the instrument, allow a short warm-up period. Two or three minutes is normally sufficient for most purposes.

If you are using this Bridge for the first time, it will be helpful at this stage to get to know the recommended technique of reading the main dial before making a measurement.

The coarse control moves the pointer of the outer dial in steps equal to one dial division; the fine control for the inner dial is continuously variable, and the range 0 to 100 of the inner scale is equivalent to one division of the outer scale. Note that the coarse control is a switch with light indexing for ease of operation. No attempt should be made to obtain a setting between the marks.

2.2 (continued)

The value of a component is most easily found by first noting the reading of the outer scale followed by the reading of the inner scale, and then putting in the decimal point by referring to the figure displayed in the nearest scale window. Typical examples are shown below :-

Range:	10 Ω	1000 kΩ	0.1 μF	100 μH
Outer dial:	08--	63--	104--	99--
Inner dial:	43	08	10	102
Value:	0.843 Ω	630.8 kΩ	0.10410 μF	100.02 μH

2.3 CONNECTING THE COMPONENT

Connect the component between the HI and DET terminals, using short leads where possible. Small components can often be directly supported by the test terminals or laid on the insulated component platform. Note the following precautions :-

(a) Impedance between the HI side of the component and earth shunts the 'balance' arm of the bridge and may result in an inaccurate reading.

(b) Stray pick-up on the lead to the DET terminal is applied to the input of the bridge detector and may result in difficulty in obtaining a clear balance indication. Using a screened lead, with the screen connected to the E terminal, helps to avoid this effect.

(c) The presence of an earth on either side of the component will short-circuit the bridge and make measurement impossible.

(d) The bridge energizing voltages appearing at the test terminals (see Data Summary) are sufficiently small to cause little risk of damage to the component or shock to the operator. The a.c. terminal voltage variations when measuring L or C are shown on drwg. no. XD 30557, at the end of the handbook.

2.3 (continued)

(e) When measuring screened inductors, the screen may be left disconnected, or connected to the E terminal.

2.4 RESISTANCE MEASUREMENT

Resistance can be measured at d.c. only. The 1 kc/s-10 kc/s switch and the loss balance controls are inoperative.

(1) Set the LCR switch to R (or Rx10 if the anticipated value is above 10 MΩ).

(2) If the approximate resistance is known, set the RANGE switch so that the anticipated value lies above the left-hand scale window (unless the value is likely to be less than 1 ohm), set the fine (inner) BALANCE control to about the middle of its range, then carry on as in step (4).

If the resistance value is completely unknown, set the RANGE switch to its highest setting and continue as follows :-

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat from (3); continue to do this until the meter reading increases, showing that the correct range has been reached. If it still decreases when the bottom range has been reached, then the resistance value is less than 1 ohm.

(4) Having selected the correct range, start from the left-hand scale window and rotate the coarse control clockwise (or counter-clockwise if the value is below 1 ohm) to obtain a minimum meter reading; then rotate the fine BALANCE control to obtain a meter reading as near as possible to zero before reading the resistance value from the BALANCE dial.

Note: It may be observed that many composition resistors show a continuous drift in value.

2.4.1 Measuring Low-Wattage Resistors

On the lower ranges, the effect of the 4 volts e.m.f. at the test terminals may have to be considered when measuring low-wattage resistors. The voltage across the resistor when connected to the DET and HI terminals will be less than the open-circuit e.m.f., and the resultant dissipation may be estimated from the following table.

Test Resistor ohms	Dissipation watts
0.5	0.1
1	0.175
5	0.5
20	0.52
50	0.25
100	0.175
500	0.035

When it is considered that even this low value of dissipation is too great for the particular test conditions, the test resistor should be placed in series with a resistor of known value as shown in the example below.

To measure a 75-ohm resistor rated at 0.1 watt :-

(1) Select a 680-ohm resistor of ample rating, and measure its value accurately; e.g., 676.4 ohms.

(2) Add the unknown resistor in series with the 676.4 ohm resistor and measure the total value; e.g., 750.3 ohms.

Difference : 73.9 ohms.
Dissipation : 0.0016 watt.

2.5 INDUCTANCE MEASUREMENT

When measuring inductance, the loss balance controls must be used to balance out the resistive component of the inductor. The loss balance dial is direct-reading at 1 kc/s only; readings on either scale must be multiplied by 10 when measuring at 10 kc/s, further details of which are given in Section 2.5.4. The main balance dial is direct reading at all frequencies.

Most audio and power-frequency inductors may be measured at 1 kc/s using the 0-30 Q range as described in the general measuring procedure, Section 2.5.1.

For small low-Q inductors such as r.f. coils it is better to use 10 kc/s and the 0-3 Q range in accordance with Section 2.5.2.

For large inductors with a low self-resonant frequency or small inductors with a saturable core, special precautions are described in Section 2.5.3.

2.5.1 General Procedure

(1) Set the controls as follows :-

LCR switch	:	L
D-Q switch	:	Q = 0-30
1 kc/s - 10 kc/s switch	:	1 kc/s
LOSS BALANCE control	:	About 10
FINE Q control	:	Mid-way
FINE BALANCE control	:	Mid-way

(2) If the approximate inductance is known, set the RANGE switch so that the anticipated value lies above the left-hand scale window (except for values less than 10 μH) and carry on as in step (4).

If the inductance value is completely unknown, adjust the RANGE switch to its highest setting, and continue as follows :-

2.5.1 (continued)

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat (3) until the meter reading increases, showing that the correct range has been reached. If the meter reading continues to decrease after the bottom range has been reached, then the inductance value is less than 10 μH.

(4) Having selected the correct range, start from the left-hand scale window and rotate the coarse BALANCE control clockwise (or counter-clockwise if the value is below 10 μH) to obtain a minimum meter reading. It helps if this is done fairly quickly since, until the Q setting is approximately correct, the balance indication will not be sharp. Therefore, it is best to adjust the LOSS BALANCE and the coarse BALANCE controls together for a sharp null.

Finally obtain as near as possible a zero meter reading by adjustment of the fine BALANCE control together with the LOSS BALANCE (and FINE Q if the loss adjustment is critical).

2.5.2 Measuring Low Inductance (R.F. Coils)

Small inductors - for example, r.f. coils - are difficult to measure on any audio frequency bridge because of their low Q at a test frequency which may be many thousands of times less than their operating frequency. Such inductors, being predominantly resistive at a.f., require a more exacting measurement procedure involving two separate balancing operations before a satisfactory final balance indication can be obtained.

The interdependence between the BALANCE and LOSS BALANCE controls becomes increasingly apparent as the value of Q decreases. It is for this reason that measurements should preferably be made at 10 kc/s since the Q appears to be 10 times greater at this frequency.

2.5.2 (continued)

A recommended measurement procedure is detailed below; this gives an approximate first balance which is often within 10% - a great help in evaluating these difficult components.

(1) Set the controls as follows :-

LCR switch	:	L
D-Q switch	:	Q = 0-3
1 kc/s-10kc/s	:	10 kc/s
LOSS BALANCE control	:	Fully clockwise
FINE Q control	:	Mid-way
COARSE BALANCE control	:	0

First measure the approximate inductance as follows :-

(2) Turn the RANGE switch to its highest setting. Using rapid movements with the fine BALANCE control, search for a balance point, reducing the range a step at a time. (Ignore the slow recovery of the meter pointer due to the a.g.c. system.) Reduce the range by one step if the balance position is below 10 on the fine BALANCE dial.
Note: If the inductor Q is extremely low, the balance indication will be rather flat.

(3) Read the inductance value (using table 1 as a guide if necessary) from the fine BALANCE dial. This will only be an approximate value, although the sharper the balance indication the more accurate is the value obtained.

TABLE 1

Left-hand Scale Window Value	Fine BALANCE Range
10 H	1 H
1 H	100 mH
100 mH	10 mH
10 mH	1 mH
1 mH	100 µH
100 µH	10 µH
10 µH	1 µH

2.5.2 (continued)

To measure the coil accurately, proceed as follows :-

(4) Set the RANGE and coarse BALANCE controls to indicate the approximate value obtained above, and re-balance the bridge using the LOSS BALANCE controls to obtain the lowest meter reading.

(5) Offset the coarse BALANCE control a step at a time (usually counter-clockwise), re-balancing with the LOSS BALANCE controls to obtain as near as possible a zero reading. Use the FINE Q control if the loss adjustment becomes critical.

Do not stop at the first lowest reading, but continue to adjust, ultimately using the fine BALANCE and FINE Q controls alternately to obtain a zero reading - or at least within one or two divisions - on the meter scale.

2.5.3 Measuring Iron-Cored Inductors

To avoid errors in measurement, inductors having a low self-resonant frequency should not be tested at 10 kc/s. If their self-resonant frequency is lower than about 5 kc/s, then test results even at 1 kc/s will be in error - inductance will appear high, and magnification low. It will be found that 1 henry is the practical upper limit for measurements at 10 kc/s.

These errors will increase rapidly as the self-resonant frequency of the inductor approaches the test frequency and it is, of course, impossible to measure an inductor which resonates below 1 kc/s, since such a component will exhibit capacitive reactance. This effective capacitance may be measured on the bridge, but it will appear to have a poor dissipation factor. The inherent capacitance of the bridge at the test terminals is low - approximately 0.08 μμF - and will contribute little to lowering the self-resonant frequency of the component.

2.5.3 (continued)

Shunt capacitance however, due to the positioning of the components and the arrangement of the test leads, may lead to appreciable errors in measurement. Such errors, which will increase with frequency, can be minimized by careful positioning of the component, using short well-spaced leads and, whenever possible, supporting it on the insulated platform on top of the instrument.

Core Saturation

If the inductor is of such a type that its core may become easily saturated, it is advisable to use 10 kc/s and, if possible, to switch to the highest range that still covers the component value (by measuring a 10-mH inductor on the 10- to 100-mH range instead of the 0- to 10-mH range) thereby reducing the current through the inductor windings.

Note: Iron- or ferrite-cored inductors are particularly liable to pick up stray radiation which, applied to the bridge via the DET terminal, will tend to mask the balance point indication. To check for this effect, insert an unconnected telephone plug into the EXT. OSC. jack in order to switch off the internal oscillator. Any reading on the meter is now due to stray pick-up, and the inductor should be turned or repositioned to minimize the effect.

2.5.4 Notes on Inductive Loss Balancing

(1) Definitions

$$Q = \text{magnification factor} = \frac{\omega L}{R} = \frac{X}{R}$$

$$D = \text{dissipation factor (or tan } \delta \text{ or loss tangent)} = \frac{1}{Q} = \frac{R}{X}$$

$$\cos \phi = \text{power factor} = \frac{R}{\sqrt{X^2 + R^2}} = \frac{R}{Z}$$

($\cos \phi \simeq D$ for values less than 0.1)

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2.5.4 (continued)

(2) Fine Q Control

This is in circuit on the 0-3 and 0-30 Q ranges, but not on the Q > 30 range. Since its range is only 0.06 Q at 1 kc/s and 0.6 Q at 10 kc/s, it is only effective towards the lower end of the LOSS BALANCE range and has a negligible effect on the dial reading accuracy.

(3) LOSS BALANCE Dial Reading

The LOSS BALANCE dial indicates either Q or D depending on the Q range selected. This is shown in the following tables together with the scale multiplying factors appropriate to the bridge operating frequency.

(a) Measurements at 1 kc/s

D-Q Switch position	LOSS BALANCE dial reading	Q range
Q = 0-30	Q scale is direct reading.	0-30
Q > 30	D scale is direct reading; $Q = \frac{1}{D}$	30-∞
Q = 0-3	Uncalibrated, but dividing the Q scale reading by 10 gives a fair approximation.	0-3

(b) Measurements at 10 kc/s

D-Q Switch position	LOSS BALANCE dial reading	Q range
Q = 0-30	Multiply Q scale by 10.	0-300
Q > 30	Multiply D scale by 10; $Q = \frac{1}{\text{D scale reading} \times 10}$	3-∞
Q = 0-3	Q scale is direct reading.	0-30

2.5.4 (continued)

(c) Measurements at other frequencies

(using external oscillator and detector)
F = oscillator frequency in kc/s

D-Q switch position	LOSS BALANCE dial reading
Q = 0-30	Multiply Q scale by F.
Q > 30	Multiply D scale by F; $Q = \frac{1}{\text{D scale reading} \times F}$
Q = 0-3	Multiply Q scale by 10 F.

(4) Series or Parallel Values

The Bridge measures the inductive and resistive components of an inductance as a series network when the D-Q switch is set to Q = 0-30 or Q = 0-3, and as a parallel network when switched to Q > 30.

The equivalent series (L_s) or parallel (L_p) inductance are related by the expression

$$L_s = L_p \left(\frac{1}{1 + D^2} \right)$$

Therefore, when switched to Q > 30, the indicated parallel inductance can be converted to the more familiar series form by multiplying by $1/(1 + D^2)$. The difference is normally very small : about 1% for D = 0.1 (Q = 10) and 0.1% for D = 0.03 (Q = 33).

2.5.5 Using the D.C. Choke Adaptor Type TM 6113

This Adaptor is designed to operate at 1 kc/s but, in order to accommodate frequency variations between individual Bridges, one of the 'isolating' tuned circuits within the Adaptor is variable, and it is therefore left to the user to adjust the Q TRIMMERS (switch and variable capacitor) to match the frequency of the Bridge in use. Once set, there is no need to make any further adjustments to these controls unless the Adaptor is used on a different Bridge.

The Q TRIMMERS are so called because their correct adjustment is essential if accurate Q readings are to be obtained.

When using the Adaptor, which is connected to the Bridge by means of permanently attached leads, d.c. up to 200 mA from an external source may be passed through the windings of the inductor under test while the measurement is being made.

To measure an inductor in this way (in the range 100 mH to 100 henrys), proceed as follows :-

(1) With the Adaptor disconnected, measure an inductor on the Bridge at 1 kc/s, note the control settings, and leave the inductor in place. If the balance indication is vague, this may be due to interference picked up by the inductor - see Section 2.5.3.

(2) Join the E terminal on the Adaptor to the E terminal on the Bridge, or a convenient place on the case.

(3) Join the brown (Hi) Adaptor lead to the HI terminal on the Bridge. This will usually cause a change in balance as indicated on the meter. Minimize this change by operating the Q TRIMMERS. A small adjustment to the fine BALANCE will also be necessary; if this is insufficient, move the coarse BALANCE by one step and readjust the fine BALANCE.

2.5.5 (continued)

If the Bridge frequency is further off tune than the limits of the Q TRIMMERS permit, then readjustment of the Q control on the Bridge will be necessary. In such circumstances the inductance measurement accuracy will not be seriously affected unless the Q control is grossly offset.

(4) Finally disconnect the inductor and connect the screened Lo lead from the Adaptor to the DET terminal on the Bridge.

Chokes may now be measured, with appropriate d.c. polarization, by connecting them across the Hi and Lo terminals on the Adaptor. The normal Bridge controls should be used without further readjustment of the Q TRIMMERS.

Accuracy

Without very careful precautions it is not easy to obtain consistently accurate measurements of the inductance of ordinary transformers and chokes with laminated cores. The reading of inductance will often be found to vary according to their position relative to earthed objects, mains power leads, etc. Movement of their leads can often change the answer. These effects are due to imperfections of ordinary alloys as a core material, and to stray capacitance between leads. The errors are, in general, proportional to inductance.

When measuring chokes in excess of about 20 henrys, slight residual coupling between the tuned circuits in the Adaptor may give rise to false balance. Careful arrangement and screening have reduced the largest error at 100 henrys to about 10%. This error reduces with reduced inductance to an error which normally does not exceed 3% at 20 henrys and below. Q accuracy, however, degenerates progressively above about 10 henrys - but this is a requirement that is seldom encountered.

2.6 CAPACITANCE MEASUREMENT

When measuring capacitance, the loss balance controls must be used to balance out the resistive component of the capacitor.

All capacitors may be measured at 1 kc/s, and most with the D-Q switch set to the Q > 30 range. The low value of Bridge voltage allows the measurement of electrolytic capacitors provided they have been formed and their Q is greater than 5.

Do not overlook stray capacitances (detailed in Sect. 2.6.2) or the fact that lead inductance may introduce errors when measuring large capacitance at the higher frequencies.

In-situ measurements can be made subject to some limitations - see Section 2.6.2.

2.6.1 General Procedure

(1) Set the controls as follows :-

LCR switch	:	C
D-Q switch	:	Q > 30 (or 0-30 for electrolytics)
1 kc/s - 10 kc/s switch	:	1 kc/s
LOSS BALANCE control	:	Mid-way
FINE Q control	:	Mid-way
FINE BALANCE control	:	Mid-way

(2) If the approximate capacitance is known, set the RANGE switch so that the anticipated value is above the left-hand BALANCE scale window (except for values less than 10 μμF), and carry on as in step (4).

If the capacitance value is completely unknown, then select the highest capacitance range and continue as follows :-

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

2.6.1 (continued)

If the meter reading decreases then reduce the range setting by one step and repeat (3) until the meter reading increases, showing that the correct range has been reached. If it still decreases when the bottom range is reached, then the capacitance value is less than 10 μμF.

(4) Having selected the correct range, start from the left-hand scale window and rotate the coarse BALANCE control clockwise (or counter-clockwise for values below 10 μμF) to obtain the lowest meter reading.

Final balance is achieved by adjusting the LOSS BALANCE and coarse BALANCE controls alternately until the lowest meter reading is obtained. Then adjust the LOSS BALANCE and fine BALANCE controls to obtain as near as possible a zero meter reading.

2.6.2 In-Situ Capacitance Measurement

Capacitors may be measured in situ, that is without disconnecting them from their associated circuit, provided the following precautions are observed.

(1) Neither the HI nor the DET terminal of the Bridge must be earthed. This means that, if one side of the capacitor is connected to an earthed chassis, then the chassis itself must be isolated from earth by disconnecting the power supply lead, etc.

(2) The capacitance between the leads may have to be considered, and subtracted if significant.

(3) Resistance between the HI terminal and earth may make loss balancing difficult and should therefore be kept above 5 MΩ.

(4) Capacitance between the HI terminal and earth results in an error of -1% per 1000 μμF.

(5) Interference picked up on the lead to the DET terminal may mask the balance point.

2.6.2 (continued)

To reduce the effects of (3) and (5) it may be worth using screened leads for the connections, the screens being joined to the E terminal. This will add to the effect of (4) and, if this is likely to be significant, the error incurred can be found by the following substitution method :-

After balance has been reached, note the capacitance reading; then, without disturbing the test arrangement, disconnect - without moving - the leads from the test terminals, and substitute a capacitor of similar value to the capacitor under test. This should be of small physical size, and connected directly to the test terminals. Measure its value accurately, and then, with this capacitor still connected, re-connect the lead to the HI terminal and note the percentage change in the measured value when the Bridge is adjusted for balance again. This percentage error should then be used to correct the original measurement.

For example :

Value obtained by in-situ measurement = 120 μμF

Value of substitution capacitor = 110 μμF

Value of substitution capacitor with lead reconnected = 99 μμF

Percentage change = $\frac{-(110-99)}{110} \times 100\%$ = -10%

Corrected value for in-situ measurement = 120 μμF + 10%
= 132 μμF

Avoiding the effects of (3) and (4) often leads to conflicting requirements, since the large mass of the capacitor (e.g. the chassis) increases the stray capacitance effect if connected to the HI terminal and may introduce pick-up if connected to the DET terminal. It is generally better to connect it to the HI terminal and correct for the error rather than try to eliminate the pick-up.

2.6.3 Notes on Capacitive Loss Balancing *

The information given for inductive loss balancing in parts (1) to (3) of Section 2.5.4 applies equally for capacitors; however, since most capacitors have a dissipation factor of less than 0.03, measurement will generally be made at 1 kc/s using the $Q > 30$ range, in which case the D scale of the LOSS BALANCE dial is direct reading and the FINE Q control is inoperative.

The Bridge measures the resistive and capacitive components of a capacitor as a series network when the D-Q switch is set to $Q > 30$, and as a parallel network when set to $Q = 0\text{-}30$ or $Q = 0\text{-}3$. The equivalent parallel (Cp) and series (Cs) capacitances are related by the expressions

$$Cp = \frac{Cs}{1 + D^2}$$

$$Cs = Cp \frac{(1 + Q^2)}{Q^2}$$

Therefore, when using the 0-30 Q range to measure a lossy capacitor, the indicated parallel capacitance may be converted to the series form by multiplying by $(1 + Q^2)/Q^2$.

It is important to note the larger difference between Cs and Cp as the Q of the test component is reduced, viz :-

$Q = 5$	$Cs = Cp + 4\%$
$Q = 3$	$Cs = Cp + 11\%$
$Q = 2$	$Cs = Cp + 25\%$

With electrolytic capacitors in particular, it is found that, provided that the Q is greater than 5, the results are fairly reliable, but as Q decreases, the interpretation of the measurement after applying the Cs/Cp relationship does not necessarily give results having any great degree of accuracy. They are particularly prone to be frequency dependent and, in practice, apparent error up to 50% can arise between their claimed value and the value measured on the Bridge, both of which may be correct; this confusion usually arises because such capacitors are commonly tested during manufacture at 50 or 60 c/s.

* See also Amendment Sheet No. 642/1.

2.7 USE OF EXTERNAL OSCILLATOR AND DETECTOR

For measurements at frequencies other than 1 or 10 kc/s the bridge can be energized by an external audio oscillator at frequencies down to about 50 c/s. When plugged into the EXT. OSC. jack the oscillator output should be between 1 and 2 volts; inserting the plug automatically switches off the internal oscillator.

The use of an external oscillator also necessitates the use of an external detector since the internal detector's frequency range is limited by filters to 1 and 10 kc/s only; these filters are automatically disconnected when a plug is inserted in the EXT. DET. jack. As the impedance ratios of the bridge favour high frequencies, harmonics in the oscillator input will be accentuated in the output to the detector, and this may necessitate the use of filters in the external detector circuit. This is particularly important below 200 c/s; at higher frequencies an oscilloscope may be used to observe the balance but below 200 c/s extra selectivity and extra gain will be found necessary.

Although the main BALANCE dial is direct reading at any frequency, the reading of the LOSS BALANCE dial must be multiplied by f/1000, where f = external oscillator frequency in c/s. If f is less than 1 kc/s, an external loss balance control may have to be added - see Section 2.7.1 below.

2.7.1 External D-Q Terminals *

These terminals, which are always linked for measurements at 1 or 10 kc/s, enable an external potentiometer to be connected in series with the LOSS BALANCE controls. This is only necessary in order to maintain continuous Q coverage when using an external bridge-energizing oscillator at frequencies below 1 kc/s.

For example, at 500 c/s the Q and D ranges are divided by 2, giving a total Q cover of only 0 to 15 and 60 to ∞; the external potentiometer is needed to bridge the gap.

* See also Amendment Sheet No. 642/1.

2.7.1 (continued)

A suitable value, Rv, for an external Q potentiometer is given by

$$Rv = \frac{Q \text{ max}}{f} \times 1592 \text{ k}\Omega$$

where Q max = maximum expected Q of component,
f = test frequency in c/s.

The balance procedure is then normal except that the external Q potentiometer is used as well as the two internal controls, but the Q value can not be obtained from the reading on the dial. If this is required, set the LOSS BALANCE control to zero and rebalance using only the external Q potentiometer; then disconnect the potentiometer and measure its value, R.

$$Q = \frac{Rf}{1592}$$

where R is in kΩ and f in c/s.

High-dissipation capacitors such as electrolytics may require an external D control in order to obtain the more realistic series equivalent value of capacitance. 5 kΩ is suggested as a suitable value to cover all normal requirements. The dissipation factor is given by

$$D = \frac{Rf}{1592}$$

where R is in kΩ and f in c/s. The value of R is found in the same way as for Q measurement above.

3 TECHNICAL DESCRIPTION

It is intended that the description given in the CIRCUIT SUMMARY below should be read in conjunction with the Functional Diagram. Reference should be made to the Circuit Diagrams when reading the more detailed information following this Section. The Functional and Circuit Diagrams are included at the end of this handbook.

3.1 CIRCUIT SUMMARY

Two separate internal energizing sources are available to the measuring bridge for the evaluation of reactive and resistive components. When measuring reactive components, the measuring bridge may be energized either from an internal 1-kc/s or 10-kc/s oscillator-amplifier, or from an external source via the front panel socket and an internal amplifier, V2b. When measuring resistance, the bridge is energized by d.c. from the rectified output of an l.t. secondary winding on the mains transformer.

The correct energizing voltage, and the measuring bridge circuit arrangement appropriate to the component under test, are automatically selected by the LCR switch. For inductance and capacitance measurement, the out-of-balance voltage from the measuring bridge is applied directly to the first amplifying valve, V3. For resistance measurement, the d.c. output from the bridge is first interrupted - or chopped - by means of a vibrator.

After amplification by V3, and by the two-stage amplifier, V4, the output from the bridge is then applied to the diode detector, MR2. This diode performs the dual function of rectifying the output from V4 in order to provide d.c. to operate the meter, and providing an a.g.c. voltage. The provision of an a.g.c. system obviates the need for a sensitivity control.

Tandem 1-kc/s and 10-kc/s tuned filters which are normally connected in the circuit across the output of the first amplifier, V3, are automatically disconnected if an external detector (e.g. oscilloscope) is plugged in.

3.2 CIRCUIT DESCRIPTION

3.2.1 Measuring Bridge A.C. Supply

The double triode valve V2 (Drawing No. XD 32020 Sheet 1) combines the functions of oscillator and amplifier for energizing the measuring bridge when switched for inductance or capacitance measurement.

Valve section V2a is connected as a phase-shift oscillator; switched ladder networks provide the necessary circuit constants for the maintenance of oscillations at 1 and 10 kc/s. The three-stage network, including the preset resistor RV3, controls the oscillation at 1 kc/s, and the 4-stage network which includes preset resistor RV4. controls the oscillation at 10 kc/s. The method of setting up the preset resistors RV3 and RV4 is described in Section 4.6.1.

Valve section V2b functions as an amplifier, receiving its input either from the grid circuit of V2a or from an external source via the EXT. OSC. socket, JKA. When the external oscillator supply is plugged in, the contacts of JKA automatically disconnect and earth the internal oscillator output.

Transformer T2 couples the output from the amplifier to the measuring bridge input; it is a step-down transformer of specialized design which affords efficient matching into the bridge impedance, and possesses the properties of low self-capacitance and small external magnetic field. Resistor R11, shunted across the primary winding of the transformer, minimizes the reaction on the oscillator due to changes in bridge impedance. The output from T2 is routed to the measuring bridge input via the LCR switch wafers SBd and SBf (Drawing No. XD 32020, Sheet 2), and its screen is permanently connected to the standard capacitance (C12 to C19).

3.2.2 Measuring Bridge D.C. Supply

The d.c. voltage required by the bridge when measuring resistance is obtained from the rectified outputs of secondary windings LT3 and LT5 on the mains transformer. When switched to R, the contact of the LCR switch wafer SBg selects LT3; the output is then applied to the bridge via the full-wave rectifier, MR2. When switched to Rx10, windings LT3 and LT5 are selected, thus providing increased voltage in order to retain bridge sensitivity for the higher resistance range.

3.2.3 Measuring Bridge Circuits

The choice of measuring bridge circuit (Circuit Diagram, Sheet 2) is effected by the LCR selector switch. Operating this switch brings into use the circuit arrangement, and the energizing voltage (described in Sections 3.2.1. and 3.2.2 above), to suit the component under test. Simplified circuits of different bridge circuit arrangements can be seen on the Functional Diagram.

Resistance Bridge. For resistance measurement, the circuit is connected as a Wheatstone bridge. The component under test, and R26 (or R25/R24 for Rx10), constitute two fixed bridge arms. Two variable resistive arms are provided by the RANGE and BALANCE controls respectively.

The RANGE switch, SE, switches any one of the resistors R15 to R23 and associated components into circuit depending on the range selected, while the BALANCE controls enable a coarse and fine adjustment to be made to the resistance in this arm of the bridge by means of switched resistors R27 to R45 and the potentiometer RV12.

Inductance Bridge. In this bridge circuit arrangement, the component under test is compared with a standard capacitance value in an opposing or 'standard' arm of the bridge, while the loss in the component is balanced out by a variable resistance introduced into the arm either in series or in parallel with the standard capacitance.

The standard capacitance consists of the parallel connected capacitors C12 to C18 (some of which may have been disconnected during the initial setting-up and calibration procedure), and the final adjustment preset capacitor C19. With the D-Q switch moved to Q = 0-3 and Q = 0-30, the FINE Q variable resistor, RV8, in series with either LOSS BALANCE resistors RV5 and RV6, is placed in parallel with the standard capacitance. In these switch positions, it is the series inductance value that is indicated on the main BALANCE dial. When the D-Q switch is moved to $Q > 30$, these resistors are disconnected and instead, RV7 (also ganged with RV5 and RV6) is placed in series with the standard capacitance.

3.2.3 (continued)

Capacitance Bridge. When changing from inductance to capacitance measurement, the standard arm of the bridge is interchanged in position with the main balance arm by the contacts of the LCR switch.

As for inductance measurement, the arrangement of the standard arm will depend upon the loss in the component under test. A typical arrangement for the measurement of capacitance and dissipation factor (D or tan δ) is when the standard capacitance (capacitors C12 to C19 as described for the inductance bridge) is in series with the LOSS BALANCE variable resistor RV7. Range switching and main balancing adjustment remains the same as for inductance measurement.

3.2.4 Amplifier-Detector

This circuit (diagram Sheet 3) employs two valves, a pentode, V3, and a double triode, V4, in a circuit arrangement consisting of three stages of amplification, followed by a germanium diode detector MR2, feeding the balance meter and the a.g.c. line.

When resistance is measured, the out-of-balance d.c. voltage from the bridge is applied via a contact of the LCR switch wafer SBb and an R-C filter network to the vibrating contacts of the chopper relay RL. The R-C filter network affords smoothing to the out-of-balance bridge voltage and attenuates any supply-frequency hum pick-up on the test component. The vibrating contacts of the relay perform a chopping action at twice the supply frequency, thereby converting the d.c. into a.c. at approximately 100 c/s, which is then applied to the grid of V3 via R51 and C38.

The relay coil is energized by the secondary winding LT2 - the circuit to the coil being completed via the switch wafer SBh when the LCR switch is turned to either R or Rx10. The hum-bucking potentiometer RV2 (shown on Sheet 1) connected in parallel with LT2 and the relay coil, minimizes the effect of mains hum pick-up via the relay contacts.

3.2.4 (continued)

When measuring inductance and capacitance, the out-of-balance voltage from the bridge is applied to the grid of V3 via the contacts of the LCR switch wafer SBb and capacitors C37 and C38.

Switched filter circuits between the anode of V3 and the grid circuit of V4 are automatically brought into use by the action of the LCR switch. When the switch is set to R or Rx10, the low-pass R-C network R58 and C43 shunts the output of V3 via the contacts of switch wafer SBb, eliminating the high frequency components in the waveform produced by the vibrator relay. When the LCR switch is moved to either L or C, capacitor C43 is replaced by two rejector circuits connected in tandem. These circuits, which consist of coils L1 and L2 together with their associated shunt capacitors, offer maximum circuit sensitivity at the internal oscillator frequencies of 1 and 10 kc/s. Precise preset tuning of L1 and L2 is achieved by means of tapes coated with a graded film of iron powder: adjusting these tapes varies the effective air-gap in the ferrite cores.

Plugging in an external detector automatically disconnects the 1- and 10-kc/s filters at the contacts of the EXT. DET socket, JKB.

The series-connected components C36 and R52, which shunt the first amplifier valve, V3, via the contacts of the D-Q switch wafer SDb reduce the gain of this stage when measuring low-Q components.

Conventional R-C coupling is employed between V4a and V4b. Output for the external detector via the socket JKB is taken from the cathode of V4b, while output from the anode is applied to the diode MR2, and thence to the BALANCE meter and the a.g.c. line. The a.g.c. voltage is applied to the grid of V3 via R53 from the tapping at the junction of C47 and R66. The time constant of this circuit is such that the a.g.c. delay is 10 seconds. This arrangement has the advantage that comparatively fast changes in bridge out-of-balance voltage are fully displayed initially on the BALANCE meter, after which the gain of the amplifier is slowly and automatically adjusted by the a.g.c. to suit the new conditions.

3.2.5 Power Supplies

The two tapped primary windings of the mains transformer, T1, permit a series or series-parallel arrangement in order to cover the input ranges 100 to 130 volts and 200 to 250 volts at 40 to 60 c/s. Voltage adjustments are made by means of a plug-in type mains panel as described in Section 4.3.

The h.t. supply is derived from a full-wave rectifier V1 via resistance-capacitance smoothing. The heater of V1 is supplied separately from the secondary winding LT1, while secondary winding LT4 is common to the heaters of V2, V3 and V4. LT3/LT5 provides d.c. at two levels via the rectifier MR1, and LT2 provides the energizing source for the vibrator relay - these are switched into use when measuring resistance, as described in Section 3.2.2.

3.2.6 D.C. Choke Adaptor Type TM 6113

Referring to the Circuit Diagram, Fig. XC 31308, it will be seen that the external d.c. supply is applied across the winding of the inductor under test via coils L1 and L2. The tuned circuits which include L1 and L2 are tuned to resonance at 1 kc/s, and at this bridge frequency serve the purpose of significantly isolating the load due to the d.c. supply from the test terminals of the Bridge. The d.c. is prevented from flowing through the measuring bridge circuit by the presence of the capacitor C10.

To account for the variation in frequency between different instruments, the tuned circuit L1/C7 is made variable by means of the switch capacitors C1 to C6, and the trimmer capacitor, VC1. Fixed tuning only is employed for L2/C8, since this circuit only shunts the amplifier-detector input of the Bridge, and therefore does not affect the accuracy.

4 MAINTENANCE

Before making any of the adjustments or voltage checks described in the following sections, it is recommended that the instrument be allowed at least a 15-minute warm-up period.

4.1 REMOVAL FROM CASE

Place the instrument on its back and remove the four screws from the feet of the case. The front panel and chassis assembly can now be lifted clear of the case.

For better access to components, or to make adjustments to the mains input plugs as described in Section 4.3, the top plate can be lifted clear after removing five screws. Two of these screws are located beneath the component platform and operating instructions but are accessible through holes cut in the perspex backing plate.

4.2 ACCESS TO COMPONENTS

After removing the instrument from its case and taking off the top plate as described above, it is only necessary to remove the under-chassis screening plate when it will be found that all components are completely accessible for inspection or replacement.

4.3 MAINS INPUT ADJUSTMENTS

Mains input adjustments are made by means of four two-pin plugs which make contact with the connections to the transformer through a reversible masking plate. This plate is marked on one side with voltages applicable to the 200- to 250-volt range (white figures), and on the other side with voltages applicable to the 100- to 130-volt range (black figures). All the possible combinations to suit the input ranges covered by the instrument are shown overleaf.

The tapping panel is mounted on top of the mains transformer. To check or adjust the tapping plugs, it is only necessary to remove the five screws and then the top plate as described in Section 4.1.

4.4 WORKING VOLTAGES

The voltages given in Tables 1 and 2 are for guidance when servicing the instrument and are representative of the readings to be expected if measurements are made with a meter having a resistance of 20,000 ohms per volt.

On individual instruments some variation in readings can be expected due to normal variations in valve performance and component values. Check that the mains input is adjusted to suit the supply voltage before carrying out any voltage checks on the instrument.

4.5 REPLACEMENT OF VALVES

A list of valves fitted, together with suitable alternative types, will be found in the SCHEDULE OF PARTS SUPPLIED Section of this handbook. It is recommended that faulty valves should preferably be replaced with a type originally supplied in the instrument. No special selection or aging is required.

4.6 ADJUSTMENT OF PRESET COMPONENTS

After removing the instrument from its case, it will be seen that all the main components are clearly marked, hence no difficulty will be experienced in identifying any of the preset controls for which adjustment procedure is described in the following sub-sections.

Note. In the event of any wiring changes, the value of C41 may need re-selecting in order to resonate L1, the 1 kc/s filter, (see Section 4.6.3).

TABLE 1

Power Supply Voltages

Supply	Measured Between :-	Voltage
H. T. a.c.	Each h.t. tag on T1 and chassis	310 V a.c.
H. T. d.c.	Capacitor C1 positive tag & chassis	370 V d.c.
H. T. d.c.	Capacitor C2 positive tag & chassis	270 V d.c.
H. T. d.c.	Capacitor C40 positive tag & chassis*	215 V to 250 V d.c.
L. T. 1	L. T. 1 tags on T1**	6.3 V a.c.
L. T. 2	L. T. 2 tags on T1	6.3 V a.c.
L. T. 3	L. T. tags on T1	6.3 V a.c.
L. T. 4	L. T. tags on T1	6.3 V a.c.
L. T. 5	L. T. tags on T1	27 V a.c.
Bridge d.c.	Output from MR1 (LCR switch at R, test terminals open-circuited)	3.8 V d.c.
Bridge d.c.	Output from MR1 (LCR switch at R, RANGE switch at 1Ω, test terminals short-circuited)	0.4 V d.c.
Bridge d.c.	Output from MR1 (LCR switch at Rx10, BALANCE control at full-scale, test terminals open-circuited)	21 V d.c.
Bridge a.c.	Secondary tags on T2 (LCR switch set to L or C, D-Q switch at Q $>$ 30, test terminals short-circuited, RANGE switch rotated from lowest to highest range at 1 kc/s and 10 kc/s)	250-750 mV a.c.

* Actual voltage value depends upon the setting of the BALANCE control.

** Tags L. T. 1 on transformer T1 are at h.t. potential with respect to the chassis.

TABLE 2

Valve Electrode Voltages

Valve	Anode		Cathode		Grid	
	Pin No.	Voltage	Pin No.	Voltage	Pin No.	Voltage
V1 (6X4)	1 and 6	310 a.c.	7	370		
V2 (12AT7)	1	150	3	1		
	6	270	8	3		
V3 (EF86)	6	90-250*	3	2-0*	1	60-100*
V4 (12AX7)	1	130	3	1		
	6	190	8	0.6		

All voltages shown are d.c. with respect to the chassis except for V1 anodes.

* Actual voltage depends upon the setting of the BALANCE control.

4.6.1 Oscillator Preset Resistors

Adjustments to the preset resistors, RV3 and RV4 in the 1-kc/s and 10-kc/s oscillator circuits are made before the instrument is dispatched. It is not expected that further adjustment will normally be needed. If, however, it is found necessary to reset these resistors, then the resonant frequencies of the preset tuned circuits including L1 and L2 in the detector-amplifier can be used as standards. The procedure is as follows :-

(1) Connect a 1000-ohm resistor between the DET terminal and the centre E terminal.

4.6.1 (continued)

(2) Select the 100-H full-scale range.

(3) Adjust RV3 at 1 kc/s and RV4 at 10 kc/s to obtain maximum meter reading.

(4) To check the amplitude of the 1-kc/s and 10-kc/s outputs, refer to Section 4.3, Table 1.

4.6.2 Hum-Neutralizing Preset Resistors

Excessive hum is indicated by a high meter reading at balance, or it may be heard on headphones plugged in at the EXT. DET socket. This may be due to the incorrect positioning of the preset resistors RV1 and RV2. Adjustment to these variable resistors is made as follows :-

(1) Select the 10-MΩ full-scale range, and short circuit the DET and E terminals.

(2) Adjust RV1, and then RV2, for minimum deflection on the meter.

(3) Remove the short-circuit and connect a low-value resistor between the HI and DET terminals, and check that after adjusting for balance the meter reading drops to zero (or at least within one scale division).

4.6.3 Amplifier 1-kc/s and 10-kc/s Filters

The preset tuning adjustment of the filter inductors L1 and L2 in the grid circuit of the 2nd amplifier, V4a, is made before the instrument is dispatched. Accurate tape adjustment (see Section 3.2.4) is made, the surplus being cut off and the remaining ends stuck down. It is not expected that the user should adjust these inductors.

4.6.4 Bridge Preset Capacitors

To ensure good accuracy on the D scale when making capacitance measurements, the three top resistance values which are switched into the range arm of the bridge have reactance compensation added by means of the preset capacitors C24, C25, and C26. The setting of these can be checked as follows :-

4.6.4 (continued)

(1) Select the 100-μμF full-scale range.

(2) Select Q >30 and 10 kc/s, and turn the LOSS BALANCE control to indicate zero on the D scale.

(3) Connect a 100-μμF capacitor (see note below) across the DET and HI terminals; using the main BALANCE control, adjust for balance on the meter, using C26 if necessary, to obtain minimum reading.

(4) Switch to 1 kc/s and check that D=O (or nearly so) at this lower frequency. A small readjustment of the FINE BALANCE may be necessary.

The adjustment for the best balance conditions at both 1 and 10 kc/s will be found to be a compromise, but it can be considered as satisfactory if balance at both frequencies can be obtained within the first $2\frac{1}{2}$ meter scale divisions, and if the D setting for a well-defined balance is less than 0.001 at 1 kc/s. Should a large discrepancy arise in the D settings between 1 and 10 kc/s, then the test capacitor should be suspected.

(5) Repeat a similar procedure for the 1000-μμF full-scale range, using a 1000-μμF test capacitor and adjusting C25 if necessary.

(6) Repeat a similar procedure for the 0.01-μF full-scale range, using a 0.01-μF test capacitor, and adjusting C24 if necessary.

Note. The capacitors used for the above tests must be of high quality. Their accuracy is not so important, but dielectric loss must be as near to zero as possible. Polystyrene film types are recommended in preference to air dielectric types provided that the air is dry and the capacitor clean. Even the deposit left behind after handling will give rise to the discrepancy described in (4) above. It is a good precaution to dry out the test capacitors in a low temperature oven before using. An earthed (to the centre E terminal) guard ring around a test capacitor, particularly in the case of the 100-μμF one, can be used to prevent surface leakage.

4.6.5 Bridge Preset Resistors

Preset resistors RV9, RV10, and RV11 are adjusted and the Bridge checked against accurate resistance and capacitance standards during the final Factory calibration procedure. Unless the setting of these variable resistors is disturbed, it is not expected that the user will find it necessary to make any further adjustments.

4.6.6 Standard Capacitance Adjustment

The value of capacitance in the standard arm of the bridge is accurately adjusted during the Factory setting-up and calibration procedure, and it is not expected that the user will normally find it necessary to make any further adjustment.

The correct in-situ capacitance of 0.1 μF is obtained at the Factory by disconnecting one or more of the fixed capacitors C12 to C18, and making final adjustment with the variable preset capacitor C19. It is important therefore, when servicing the instrument, that these capacitors remain disconnected, and also that the position of each component in this part of the circuit remains undisturbed, otherwise measurement accuracy will be affected.

Amendment Sheet No. 642/1

for

Instruction Book No. EB 1313

The following information regarding measurements on capacitors at 10 kc/s should be added to the respective handbook sections :-

Section 2.6.3

When measuring high-grade capacitors greater than 0.01 μF at 10 kc/s it may be found that the Loss Balance control requires a negative setting to approach a complete balance null. This is due to the component under test having a better power factor than the bridge standard.

In order to obtain an accurate measurement of the capacitance with the bridge correctly at balance, the test capacitor loss should be increased slightly by adding some series resistance. The amount necessary will probably be about 50 mΩ for 1 μF, 500 mΩ for 0.1 μF, etc. This can be conveniently added in the form of a few inches of resistance wire in series with the test capacitor; if the physical length of the added wire is short, the 'C' accuracy will be unaffected.

Section 2.7.1

Measurement of capacitors of poor power factor at 10 kc/s may be found to be impeded by the limited resolution of the Loss Balanace control. This may be improved by use of an externally-connected 'fine' control. For this purpose connect a 1-ohm fixed resistor shunted by a 25-ohm variable resistor across the EXT D-Q terminals, (with the link removed).

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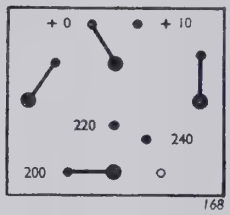
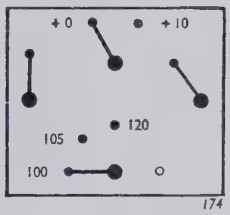
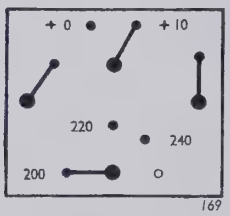
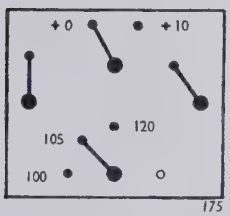
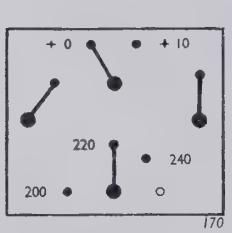
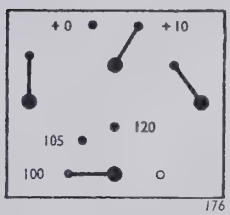
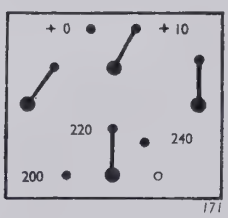
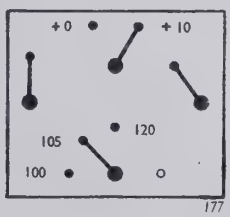
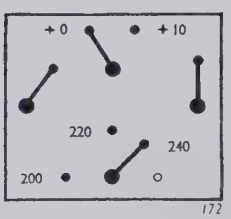
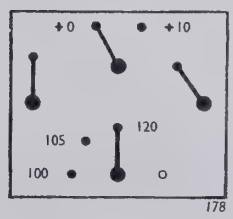
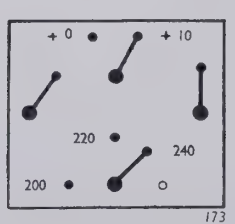
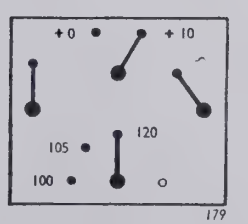
SUPPLY VOLTAGE PANEL

Masking plate and links must be positioned according to supply voltage, as shown:—

200-250 volts a.c. SUPPLY	LINKS		LINKS	100-130 volts a.c. SUPPLY
200 V	 168		 174	100 V
210 V	 169		 175	105 V
220 V	 170	To change voltage range, remove all links and reverse masking plate	 176	110 V
230 V	 171		 177	115 V
240 V	 172		 178	120 V
250 V	 173		 179	130 V

SUPPLY VOLTAGE PLUG SETTINGS

C.P. 5m. 12:60

M.I. LTD.

OPERATING INSTRUCTIONS

No. EB 1313

for

1/4% UNIVERSAL BRIDGE TYPE TF 1313

AMENDMENTS, if any, are included at the end of the handbook.

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DATA SUMMARY

for

1/4% Universal Bridge Type TF 1313

Serial Nos. JA 642/001 and above

MEASUREMENT RANGES

Inductance:	0.1 μH to 110 henrys in 7 decades; at 1 and 10 kc/s.
Capacitance:	0.1 μμF to 110 μF in 7 decades; at 1 and 10 kc/s.
Resistance:	3 mΩ to 110 MΩ in 8 decades; at d.c.
Q:	0.1 to 31 at 1 kc/s; 1 to 310 at 10 kc/s.
D (tan δ):	0.001 to 0.031 at 1 kc/s; 0.01 to 0.31 at 10 kc/s.
	Since Q = 1/D, scales combine to give extended Q coverage up to 1,000 and D up to 10.

ACCURACY (at 1 kc/s*)

Inductance :	±0.25%±0.01% of range full-scale.
Capacitance:	±0.25% ±0.01% of range full-scale.
Resistance (at d.c.):	±0.25% ±0.01% of range full-scale.
Q:	±7% ±0.1 for Q greater than 0.5*.
D:	±7% ±0.0015.
Oscillator Frequency:	±2½%.

* At higher frequencies and/or low Q the accuracy figures include an additional term $\pm F(0.01 \pm \frac{0.1}{Q})\%$ where F = frequency in kc/s.

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SCHEDULE OF PARTS SUPPLIED

The complete equipment comprises the following items :-

1. One 1/4% Universal Bridge, Type TF 1313, complete with valves, etc., as under :-

Valves :	One:	Type EF86 (6267), Pentode.
	One:	Type 6X4 (EZ90), Full-Wave Rectifier.
	One:	Type 12AT7 (ECC81), Double Triode.
	One:	Type 12AX7 (ECC83), Double Triode.
Semi-conductors:	One:	Type OA73, Germanium Diode.
Lamp:	One:	Cinch Type 79/619, Amber, Pilot Lamp.

2. Two Telephone Plugs, Type P40; for external oscillator and detector jacks.

3. One Instruction Book No. EB 1313.

ACCESSORIES AVAILABLE

D.C. Choke Adaptor, Type TM 6113; enables d.c. currents up to 200 mA from an external supply to be passed through inductors under test at 1 kc/s in the range 100 mH to 100 henrys; fitted with test leads for attaching to bridge terminals. Errors introduced by the adaptor do not generally exceed 3% and may be eliminated by simple substitution methods.

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DRAWINGS	Ref. No.
SUPPLY VOLTAGE PLUG SETTINGS	Following p 27
FUNCTION DIAGRAM	XD 35166
CHARTS OF TEST TERMINAL VOLTAGES AT BALANCE	XD 30557
CIRCUIT DIAGRAMS (3 sheets)	XD 32020
D.C. CHOKE ADAPTOR CIRCUIT DIAGRAM	XC 31308

RESIDUALS (approximate):	Inductance :	0.05 μH.
	Capacitance :	0.08 μμF.
	Resistance :	0.001 ohm.

BRIDGE ENERGIZING SOURCE

L and C:	Internal 1- and 10-kc/s oscillator; fixed output level between 250 and 750 mV. External audio oscillator may be used instead.
R:	Internal d.c. supply, nominally 4 volts; nominally 22 volts on highest range.

POWER SUPPLY: 200 to 250 volts and 100 to 130 volts, 40 to 60 c/s, 25 watts.

DIMENSIONS & WEIGHT:	Height	Width	Depth	Weight
	$11\frac{1}{2}$ in (30 cm)	$19\frac{1}{2}$ in (50 cm)	10 in (26 cm)	27 lb (12.5 kg)

Do These
2 last —

(Supply
Voltages
Should follow
P 27)

Amendment Sheet No. 642/1

for

Instruction Book No. EB 1313

The following information regarding measurements on capacitors at 10 kc/s should be added to the respective handbook sections :-

Section 2.6.3

When measuring high-grade capacitors greater than 0.01 μF at 10 kc/s it may be found that the Loss Balance control requires a negative setting to approach a complete balance null. This is due to the component under test having a better power factor than the bridge standard.

In order to obtain an accurate measurement of the capacitance with the bridge correctly at balance, the test capacitor loss should be increased slightly by adding some series resistance. The amount necessary will probably be about 50 mΩ for 1 μF, 500 mΩ for 0.1 μF, etc. This can be conveniently added in the form of a few inches of resistance wire in series with the test capacitor; if the physical length of the added wire is short, the 'C' accuracy will be unaffected.

Section 2.7.1

Measurement of capacitors of poor power factor at 10 kc/s may be found to be impeded by the limited resolution of the Loss Balanace control. This may be improved by use of an externally-connected 'fine' control. For this purpose connect a 1-ohm fixed resistor shunted by a 25-ohm variable resistor across the EXT D-Q terminals, (with the link removed).

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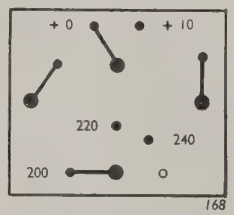
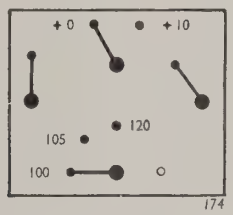
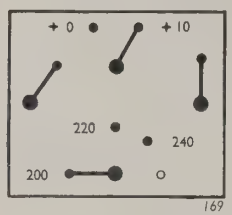
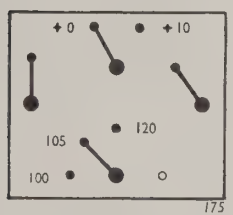
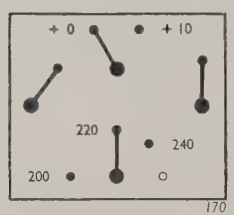
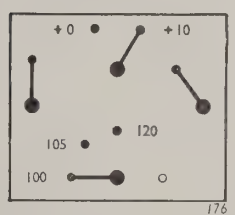
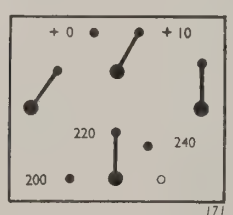
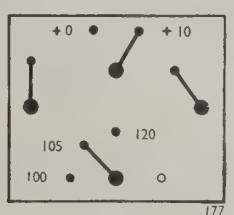
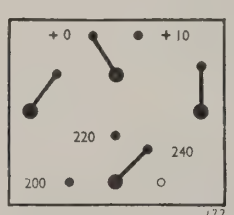
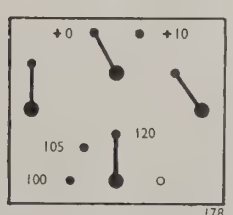
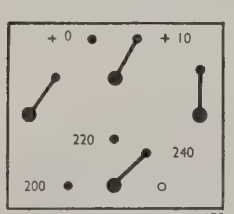
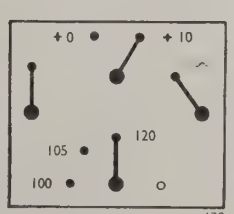
SUPPLY VOLTAGE PANEL

Masking plate and links must be positioned according to supply voltage, as shown:—

200-250 volts a.c. SUPPLY	LINKS	LINKS	100-130 volts a.c. SUPPLY
200 V	 168	 174	**100 V**
210 V	 169	 175	**105 V**
220 V	 170	To change voltage range, remove all links and reverse masking plate	 176	**110 V**
230 V	 171		 177	**115 V**
240 V	 172		 178	**120 V**
250 V	 173		 179	**130 V**

SUPPLY VOLTAGE PLUG SETTINGS

C.P. 5m. 12/60 M.I. LTD.

2 OPERATION

2.1 INSTALLATION

The 1/4% Universal Bridge is normally dispatched with its valves in position and with its mains input circuit adjusted ready for immediate use on 240 volts within the supply frequency range 40 to 60 c/s. If required, the instrument may be adjusted for operation from other supplies within the ranges 100 to 130 and 200 to 250 volts. To check or alter the tappings on the mains transformer, refer to Section 4.3.

2.2 PRELIMINARIES

Having checked that the instrument is correctly adjusted to suit the particular supply voltage to which it will be connected, proceed as follows :-

(1) If necessary, mechanically adjust the meter to indicate zero.

(2) Connect the mains lead to the supply socket. The lead is normally stowed in the left-hand case-handle recess.

(3) Put the SUPPLY switch up; the red pilot light should now glow.

(4) Before using the instrument, allow a short warm-up period. Two or three minutes is normally sufficient for most purposes.

If you are using this Bridge for the first time, it will be helpful at this stage to get to know the recommended technique of reading the main dial before making a measurement.

The coarse control moves the pointer of the outer dial in steps equal to one dial division; the fine control for the inner dial is continuously variable, and the range 0 to 100 of the inner scale is equivalent to one division of the outer scale. Note that the coarse control is a switch with light indexing for ease of operation. No attempt should be made to obtain a setting between the marks.

2.3 (continued)

(e) When measuring screened inductors, the screen may be left disconnected, or connected to the E terminal.

2.4 RESISTANCE MEASUREMENT

Resistance can be measured at d.c. only. The 1 kc/s-10 kc/s switch and the loss balance controls are inoperative.

(1) Set the LCR switch to R (or Rx10 if the anticipated value is above 10 MΩ).

(2) If the approximate resistance is known, set the RANGE switch so that the anticipated value lies above the left-hand scale window (unless the value is likely to be less than 1 ohm), set the fine (inner) BALANCE control to about the middle of its range, then carry on as in step (4).

If the resistance value is completely unknown, set the RANGE switch to its highest setting and continue as follows :-

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat from (3); continue to do this until the meter reading increases, showing that the correct range has been reached. If it still decreases when the bottom range has been reached, then the resistance value is less than 1 ohm.

(4) Having selected the correct range, start from the left-hand scale window and rotate the coarse control clockwise (or counter-clockwise if the value is below 1 ohm) to obtain a minimum meter reading; then rotate the fine BALANCE control to obtain a meter reading as near as possible to zero before reading the resistance value from the BALANCE dial.

Note: It may be observed that many composition resistors show a continuous drift in value.

1 INTRODUCTION

TF 1313 is a general-purpose impedance bridge with quarter per cent measurement accuracy over a wide range of inductance, capacitance, and resistance. It offers exceptional discrimination and resettability, wide-range loss balancing, and facilities for using an external oscillator and detector.

The single direct-reading dial used for L, C, and R measurements has coarse and fine concentric controls; the coarse one moves in 1% steps and the fine gives continuously variable interpolation between steps. Its meter gives a clear indication of the direction of the balance point even when far off-balance, bringing speed and simplicity to measurements of completely unknown components. An external audio oscillator can be plugged in where L and C measurements are required at frequencies other than the internal 1 and 10 kc/s; and the detector output is available externally to allow an oscilloscope or headphones to be used for balance indication.

This bridge can be used for precision evaluation of resistance, capacitance and inductance, for measuring dissipation factor of capacitors and Q of inductors, and for quickly identifying unknown components. Measurements on high-loss components are made easier by the low-Q range of the loss balance control and the relative independence between the adjustment of the main and loss balance controls. Its high discrimination and resettability make it particularly suitable for comparative measurements such as checking the difference between an unknown and a standard component. Measurements on inductors carrying a d. c. current can be made by using Adaptor Type TM 6113, which is available as an optional accessory.

2.2 (continued)

The value of a component is most easily found by first noting the reading of the outer scale followed by the reading of the inner scale, and then putting in the decimal point by referring to the figure displayed in the nearest scale window. Typical examples are shown below :-

Range:	10 Ω	1000 kΩ	0.1 μF	100 μH
Outer dial:	08--	63--	104--	99--
Inner dial:	43	08	10	102
Value:	0.843 Ω	630.8 kΩ	0.10410 μF	100.02 μH

2.3 CONNECTING THE COMPONENT

Connect the component between the HI and DET terminals, using short leads where possible. Small components can often be directly supported by the test terminals or laid on the insulated component platform. Note the following precautions :-

(a) Impedance between the HI side of the component and earth shunts the 'balance' arm of the bridge and may result in an inaccurate reading.

(b) Stray pick-up on the lead to the DET terminal is applied to the input of the bridge detector and may result in difficulty in obtaining a clear balance indication. Using a screened lead, with the screen connected to the E terminal, helps to avoid this effect.

(c) The presence of an earth on either side of the component will short-circuit the bridge and make measurement impossible.

(d) The bridge energizing voltages appearing at the test terminals (see Data Summary) are sufficiently small to cause little risk of damage to the component or shock to the operator. The a.c. terminal voltage variations when measuring L or C are shown on drwg. no. XD 30557, at the end of the handbook.

2.4.1 Measuring Low-Wattage Resistors

On the lower ranges, the effect of the 4 volts e.m.f. at the test terminals may have to be considered when measuring low-wattage resistors. The voltage across the resistor when connected to the DET and HI terminals will be less than the open-circuit e.m.f., and the resultant dissipation may be estimated from the following table.

Test Resistor ohms	Dissipation watts
0.5	0.1
1	0.175
5	0.5
20	0.52
50	0.25
100	0.175
500	0.035

When it is considered that even this low value of dissipation is too great for the particular test conditions, the test resistor should be placed in series with a resistor of known value as shown in the example below.

To measure a 75-ohm resistor rated at 0.1 watt :-

(1) Select a 680-ohm resistor of ample rating, and measure its value accurately; e.g., 676.4 ohms.

(2) Add the unknown resistor in series with the 676.4 ohm resistor and measure the total value; e.g., 750.3 ohms.

Difference : 73.9 ohms.
Dissipation : 0.0016 watt.

2.5.1 (continued)

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat (3) until the meter reading increases, showing that the correct range has been reached. If the meter reading continues to decrease after the bottom range has been reached, then the inductance value is less than 10 μH.

(4) Having selected the correct range, start from the left-hand scale window and rotate the coarse BALANCE control clockwise (or counter-clockwise if the value is below 10 μH) to obtain a minimum meter reading. It helps if this is done fairly quickly since, until the Q setting is approximately correct, the balance indication will not be sharp. Therefore, it is best to adjust the LOSS BALANCE and the coarse BALANCE controls together for a sharp null.

Finally obtain as near as possible a zero meter reading by adjustment of the fine BALANCE control together with the LOSS BALANCE (and FINE Q if the loss adjustment is critical).

2.5.2 Measuring Low Inductance (R.F. Coils)

Small inductors - for example, r.f. coils - are difficult to measure on any audio frequency bridge because of their low Q at a test frequency which may be many thousands of times less than their operating frequency. Such inductors, being predominantly resistive at a.f., require a more exacting measurement procedure involving two separate balancing operations before a satisfactory final balance indication can be obtained.

The interdependence between the BALANCE and LOSS BALANCE controls becomes increasingly apparent as the value of Q decreases. It is for this reason that measurements should preferably be made at 10 kc/s since the Q appears to be 10 times greater at this frequency.

2.5.2 (continued)

To measure the coil accurately, proceed as follows :-

(4) Set the RANGE and coarse BALANCE controls to indicate the approximate value obtained above, and re-balance the bridge using the LOSS BALANCE controls to obtain the lowest meter reading.

(5) Offset the coarse BALANCE control a step at a time (usually counter-clockwise), re-balancing with the LOSS BALANCE controls to obtain as near as possible a zero reading. Use the FINE Q control if the loss adjustment becomes critical.

Do not stop at the first lowest reading, but continue to adjust, ultimately using the fine BALANCE and FINE Q controls alternately to obtain a zero reading - or at least within one or two divisions - on the meter scale.

2.5.3 Measuring Iron-Cored Inductors

To avoid errors in measurement, inductors having a low self-resonant frequency should not be tested at 10 kc/s. If their self-resonant frequency is lower than about 5 kc/s, then test results even at 1 kc/s will be in error - inductance will appear high, and magnification low. It will be found that 1 henry is the practical upper limit for measurements at 10 kc/s.

These errors will increase rapidly as the self-resonant frequency of the inductor approaches the test frequency and it is, of course, impossible to measure an inductor which resonates below 1 kc/s, since such a component will exhibit capacitive reactance. This effective capacitance may be measured on the bridge, but it will appear to have a poor dissipation factor. The inherent capacitance of the bridge at the test terminals is low - approximately 0.08 μμF - and will contribute little to lowering the self-resonant frequency of the component.

2.5.4 (continued)

(2) Fine Q Control

This is in circuit on the 0-3 and 0-30 Q ranges, but not on the Q > 30 range. Since its range is only 0.06 Q at 1 kc/s and 0.6 Q at 10 kc/s, it is only effective towards the lower end of the LOSS BALANCE range and has a negligible effect on the dial reading accuracy.

(3) LOSS BALANCE Dial Reading

The LOSS BALANCE dial indicates either Q or D depending on the Q range selected. This is shown in the following tables together with the scale multiplying factors appropriate to the bridge operating frequency.

(a) Measurements at 1 kc/s

D-Q Switch position	LOSS BALANCE dial reading	Q range
Q = 0-30	Q scale is direct reading.	0-30
Q > 30	D scale is direct reading; $Q = \frac{1}{D}$	30-∞
Q = 0-3	Uncalibrated, but dividing the Q scale reading by 10 gives a fair approximation.	0-3

(b) Measurements at 10 kc/s

D-Q Switch position	LOSS BALANCE dial reading	Q range
Q = 0-30	Multiply Q scale by 10.	0-300
Q > 30	Multiply D scale by 10; $Q = \frac{1}{\text{D scale reading} \times 10}$	3-∞
Q = 0-3	Q scale is direct reading.	0-30

2.5.5 Using the D.C. Choke Adaptor Type TM 6113

This Adaptor is designed to operate at 1 kc/s but, in order to accommodate frequency variations between individual Bridges, one of the 'isolating' tuned circuits within the Adaptor is variable, and it is therefore left to the user to adjust the Q TRIMMERS (switch and variable capacitor) to match the frequency of the Bridge in use. Once set, there is no need to make any further adjustments to these controls unless the Adaptor is used on a different Bridge.

The Q TRIMMERS are so called because their correct adjustment is essential if accurate Q readings are to be obtained.

When using the Adaptor, which is connected to the Bridge by means of permanently attached leads, d.c. up to 200 mA from an external source may be passed through the windings of the inductor under test while the measurement is being made.

To measure an inductor in this way (in the range 100 mH to 100 henrys), proceed as follows :-

(1) With the Adaptor disconnected, measure an inductor on the Bridge at 1 kc/s, note the control settings, and leave the inductor in place. If the balance indication is vague, this may be due to interference picked up by the inductor - see Section 2.5.3.

(2) Join the E terminal on the Adaptor to the E terminal on the Bridge, or a convenient place on the case.

(3) Join the brown (Hi) Adaptor lead to the HI terminal on the Bridge. This will usually cause a change in balance as indicated on the meter. Minimize this change by operating the Q TRIMMERS. A small adjustment to the fine BALANCE will also be necessary; if this is insufficient, move the coarse BALANCE by one step and readjust the fine BALANCE.

2.6 CAPACITANCE MEASUREMENT

When measuring capacitance, the loss balance controls must be used to balance out the resistive component of the capacitor.

All capacitors may be measured at 1 kc/s, and most with the D-Q switch set to the Q > 30 range. The low value of Bridge voltage allows the measurement of electrolytic capacitors provided they have been formed and their Q is greater than 5.

Do not overlook stray capacitances (detailed in Sect. 2.6.2) or the fact that lead inductance may introduce errors when measuring large capacitance at the higher frequencies.

In-situ measurements can be made subject to some limitations - see Section 2.6.2.

2.6.1 General Procedure

(1) Set the controls as follows :-

LCR switch	:	C
D-Q switch	:	Q > 30 (or 0-30 for electrolytics)
1 kc/s - 10 kc/s switch	:	1 kc/s
LOSS BALANCE control	:	Mid-way
FINE Q control	:	Mid-way
FINE BALANCE control	:	Mid-way

(2) If the approximate capacitance is known, set the RANGE switch so that the anticipated value is above the left-hand BALANCE scale window (except for values less than 10 μμF), and carry on as in step (4).

If the capacitance value is completely unknown, then select the highest capacitance range and continue as follows :-

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

2.6.2 (continued)

To reduce the effects of (3) and (5) it may be worth using screened leads for the connections, the screens being joined to the E terminal. This will add to the effect of (4) and, if this is likely to be significant, the error incurred can be found by the following substitution method :-

After balance has been reached, note the capacitance reading; then, without disturbing the test arrangement, disconnect - without moving - the leads from the test terminals, and substitute a capacitor of similar value to the capacitor under test. This should be of small physical size, and connected directly to the test terminals. Measure its value accurately, and then, with this capacitor still connected, re-connect the lead to the HI terminal and note the percentage change in the measured value when the Bridge is adjusted for balance again. This percentage error should then be used to correct the original measurement.

For example :

Value obtained by in-situ measurement = 120 μμF

Value of substitution capacitor = 110 μμF

Value of substitution capacitor with lead reconnected = 99 μμF

Percentage change = $\frac{-(110-99)}{110} \times 100\%$ = -10%

Corrected value for in-situ measurement = 120 μμF + 10%
= 132 μμF

Avoiding the effects of (3) and (4) often leads to conflicting requirements, since the large mass of the capacitor (e.g. the chassis) increases the stray capacitance effect if connected to the HI terminal and may introduce pick-up if connected to the DET terminal. It is generally better to connect it to the HI terminal and correct for the error rather than try to eliminate the pick-up.

2.7 USE OF EXTERNAL OSCILLATOR AND DETECTOR

For measurements at frequencies other than 1 or 10 kc/s the bridge can be energized by an external audio oscillator at frequencies down to about 50 c/s. When plugged into the EXT. OSC. jack the oscillator output should be between 1 and 2 volts; inserting the plug automatically switches off the internal oscillator.

The use of an external oscillator also necessitates the use of an external detector since the internal detector's frequency range is limited by filters to 1 and 10 kc/s only; these filters are automatically disconnected when a plug is inserted in the EXT. DET. jack. As the impedance ratios of the bridge favour high frequencies, harmonics in the oscillator input will be accentuated in the output to the detector, and this may necessitate the use of filters in the external detector circuit. This is particularly important below 200 c/s; at higher frequencies an oscilloscope may be used to observe the balance but below 200 c/s extra selectivity and extra gain will be found necessary.

Although the main BALANCE dial is direct reading at any frequency, the reading of the LOSS BALANCE dial must be multiplied by f/1000, where f = external oscillator frequency in c/s. If f is less than 1 kc/s, an external loss balance control may have to be added - see Section 2.7.1 below.

2.7.1 External D-Q Terminals *

These terminals, which are always linked for measurements at 1 or 10 kc/s, enable an external potentiometer to be connected in series with the LOSS BALANCE controls. This is only necessary in order to maintain continuous Q coverage when using an external bridge-energizing oscillator at frequencies below 1 kc/s.

For example, at 500 c/s the Q and D ranges are divided by 2, giving a total Q cover of only 0 to 15 and 60 to ∞; the external potentiometer is needed to bridge the gap.

* See also Amendment Sheet No. 642/1.

3 TECHNICAL DESCRIPTION

It is intended that the description given in the CIRCUIT SUMMARY below should be read in conjunction with the Functional Diagram. Reference should be made to the Circuit Diagrams when reading the more detailed information following this Section. The Functional and Circuit Diagrams are included at the end of this handbook.

3.1 CIRCUIT SUMMARY

Two separate internal energizing sources are available to the measuring bridge for the evaluation of reactive and resistive components. When measuring reactive components, the measuring bridge may be energized either from an internal 1-kc/s or 10-kc/s oscillator-amplifier, or from an external source via the front panel socket and an internal amplifier, V2b. When measuring resistance, the bridge is energized by d.c. from the rectified output of an l.t. secondary winding on the mains transformer.

The correct energizing voltage, and the measuring bridge circuit arrangement appropriate to the component under test, are automatically selected by the LCR switch. For inductance and capacitance measurement, the out-of-balance voltage from the measuring bridge is applied directly to the first amplifying valve, V3. For resistance measurement, the d.c. output from the bridge is first interrupted - or chopped - by means of a vibrator.

After amplification by V3, and by the two-stage amplifier, V4, the output from the bridge is then applied to the diode detector, MR2. This diode performs the dual function of rectifying the output from V4 in order to provide d.c. to operate the meter, and providing an a.g.c. voltage. The provision of an a.g.c. system obviates the need for a sensitivity control.

Tandem 1-kc/s and 10-kc/s tuned filters which are normally connected in the circuit across the output of the first amplifier, V3, are automatically disconnected if an external detector (e.g. oscilloscope) is plugged in.

3.2.3 Measuring Bridge Circuits

The choice of measuring bridge circuit (Circuit Diagram, Sheet 2) is effected by the LCR selector switch. Operating this switch brings into use the circuit arrangement, and the energizing voltage (described in Sections 3.2.1. and 3.2.2 above), to suit the component under test. Simplified circuits of different bridge circuit arrangements can be seen on the Functional Diagram.

Resistance Bridge. For resistance measurement, the circuit is connected as a Wheatstone bridge. The component under test, and R26 (or R25/R24 for Rx10), constitute two fixed bridge arms. Two variable resistive arms are provided by the RANGE and BALANCE controls respectively.

The RANGE switch, SE, switches any one of the resistors R15 to R23 and associated components into circuit depending on the range selected, while the BALANCE controls enable a coarse and fine adjustment to be made to the resistance in this arm of the bridge by means of switched resistors R27 to R45 and the potentiometer RV12.

Inductance Bridge. In this bridge circuit arrangement, the component under test is compared with a standard capacitance value in an opposing or 'standard' arm of the bridge, while the loss in the component is balanced out by a variable resistance introduced into the arm either in series or in parallel with the standard capacitance.

The standard capacitance consists of the parallel connected capacitors C12 to C18 (some of which may have been disconnected during the initial setting-up and calibration procedure), and the final adjustment preset capacitor C19. With the D-Q switch moved to Q = 0-3 and Q = 0-30, the FINE Q variable resistor, RV8, in series with either LOSS BALANCE resistors RV5 and RV6, is placed in parallel with the standard capacitance. In these switch positions, it is the series inductance value that is indicated on the main BALANCE dial. When the D-Q switch is moved to $Q > 30$, these resistors are disconnected and instead, RV7 (also ganged with RV5 and RV6) is placed in series with the standard capacitance.

3.2.4 (continued)

When measuring inductance and capacitance, the out-of-balance voltage from the bridge is applied to the grid of V3 via the contacts of the LCR switch wafer SBb and capacitors C37 and C38.

Switched filter circuits between the anode of V3 and the grid circuit of V4 are automatically brought into use by the action of the LCR switch. When the switch is set to R or Rx10, the low-pass R-C network R58 and C43 shunts the output of V3 via the contacts of switch wafer SBb, eliminating the high frequency components in the waveform produced by the vibrator relay. When the LCR switch is moved to either L or C, capacitor C43 is replaced by two rejector circuits connected in tandem. These circuits, which consist of coils L1 and L2 together with their associated shunt capacitors, offer maximum circuit sensitivity at the internal oscillator frequencies of 1 and 10 kc/s. Precise preset tuning of L1 and L2 is achieved by means of tapes coated with a graded film of iron powder: adjusting these tapes varies the effective air-gap in the ferrite cores.

Plugging in an external detector automatically disconnects the 1- and 10-kc/s filters at the contacts of the EXT. DET socket, JKB.

The series-connected components C36 and R52, which shunt the first amplifier valve, V3, via the contacts of the D-Q switch wafer SDb reduce the gain of this stage when measuring low-Q components.

Conventional R-C coupling is employed between V4a and V4b. Output for the external detector via the socket JKB is taken from the cathode of V4b, while output from the anode is applied to the diode MR2, and thence to the BALANCE meter and the a.g.c. line. The a.g.c. voltage is applied to the grid of V3 via R53 from the tapping at the junction of C47 and R66. The time constant of this circuit is such that the a.g.c. delay is 10 seconds. This arrangement has the advantage that comparatively fast changes in bridge out-of-balance voltage are fully displayed initially on the BALANCE meter, after which the gain of the amplifier is slowly and automatically adjusted by the a.g.c. to suit the new conditions.

4 MAINTENANCE

Before making any of the adjustments or voltage checks described in the following sections, it is recommended that the instrument be allowed at least a 15-minute warm-up period.

4.1 REMOVAL FROM CASE

Place the instrument on its back and remove the four screws from the feet of the case. The front panel and chassis assembly can now be lifted clear of the case.

For better access to components, or to make adjustments to the mains input plugs as described in Section 4.3, the top plate can be lifted clear after removing five screws. Two of these screws are located beneath the component platform and operating instructions but are accessible through holes cut in the perspex backing plate.

4.2 ACCESS TO COMPONENTS

After removing the instrument from its case and taking off the top plate as described above, it is only necessary to remove the under-chassis screening plate when it will be found that all components are completely accessible for inspection or replacement.

4.3 MAINS INPUT ADJUSTMENTS

Mains input adjustments are made by means of four two-pin plugs which make contact with the connections to the transformer through a reversible masking plate. This plate is marked on one side with voltages applicable to the 200- to 250-volt range (white figures), and on the other side with voltages applicable to the 100- to 130-volt range (black figures). All the possible combinations to suit the input ranges covered by the instrument are shown overleaf.

The tapping panel is mounted on top of the mains transformer. To check or adjust the tapping plugs, it is only necessary to remove the five screws and then the top plate as described in Section 4.1.

TABLE 1

Power Supply Voltages

Supply	Measured Between :-	Voltage
H. T. a.c.	Each h.t. tag on T1 and chassis	310 V a.c.
H. T. d.c.	Capacitor C1 positive tag & chassis	370 V d.c.
H. T. d.c.	Capacitor C2 positive tag & chassis	270 V d.c.
H. T. d.c.	Capacitor C40 positive tag & chassis*	215 V to 250 V d.c.
L. T. 1	L. T. 1 tags on T1**	6.3 V a.c.
L. T. 2	L. T. 2 tags on T1	6.3 V a.c.
L. T. 3	L. T. tags on T1	6.3 V a.c.
L. T. 4	L. T. tags on T1	6.3 V a.c.
L. T. 5	L. T. tags on T1	27 V a.c.
Bridge d.c.	Output from MR1 (LCR switch at R, test terminals open-circuited)	3.8 V d.c.
Bridge d.c.	Output from MR1 (LCR switch at R, RANGE switch at 1Ω, test terminals short-circuited)	0.4 V d.c.
Bridge d.c.	Output from MR1 (LCR switch at Rx10, BALANCE control at full-scale, test terminals open-circuited)	21 V d.c.
Bridge a.c.	Secondary tags on T2 (LCR switch set to L or C, D-Q switch at Q > 30, test terminals short-circuited, RANGE switch rotated from lowest to highest range at 1 kc/s and 10 kc/s)	250-750 mV a.c.

* Actual voltage value depends upon the setting of the BALANCE control.

** Tags L. T. 1 on transformer T1 are at h.t. potential with respect to the chassis.

4.6.1 (continued)

(2) Select the 100-H full-scale range.

(3) Adjust RV3 at 1 kc/s and RV4 at 10 kc/s to obtain maximum meter reading.

(4) To check the amplitude of the 1-kc/s and 10-kc/s outputs, refer to Section 4.3, Table 1.

4.6.2 Hum-Neutralizing Preset Resistors

Excessive hum is indicated by a high meter reading at balance, or it may be heard on headphones plugged in at the EXT. DET socket. This may be due to the incorrect positioning of the preset resistors RV1 and RV2. Adjustment to these variable resistors is made as follows :-

(1) Select the 10-MΩ full-scale range, and short circuit the DET and E terminals.

(2) Adjust RV1, and then RV2, for minimum deflection on the meter.

(3) Remove the short-circuit and connect a low-value resistor between the HI and DET terminals, and check that after adjusting for balance the meter reading drops to zero (or at least within one scale division).

4.6.3 Amplifier 1-kc/s and 10-kc/s Filters

The preset tuning adjustment of the filter inductors L1 and L2 in the grid circuit of the 2nd amplifier, V4a, is made before the instrument is dispatched. Accurate tape adjustment (see Section 3.2.4) is made, the surplus being cut off and the remaining ends stuck down. It is not expected that the user should adjust these inductors.

4.6.4 Bridge Preset Capacitors

To ensure good accuracy on the D scale when making capacitance measurements, the three top resistance values which are switched into the range arm of the bridge have reactance compensation added by means of the preset capacitors C24, C25, and C26. The setting of these can be checked as follows :-

4.6.5 Bridge Preset Resistors

Preset resistors RV9, RV10, and RV11, are adjusted and the Bridge checked against accurate resistance and capacitance standards during the final Factory calibration procedure. Unless the setting of these variable resistors is disturbed, it is not expected that the user will find it necessary to make any further adjustments.

4.6.6 Standard Capacitance Adjustment

The value of capacitance in the standard arm of the bridge is accurately adjusted during the Factory setting-up and calibration procedure, and it is not expected that the user will normally find it necessary to make any further adjustment.

The correct in-situ capacitance of 0.1 μF is obtained at the Factory by disconnecting one or more of the fixed capacitors C12 to C18, and making final adjustment with the variable preset capacitor C19. It is important therefore, when servicing the instrument, that these capacitors remain disconnected, and also that the position of each component in this part of the circuit remains undisturbed, otherwise measurement accuracy will be affected.

4.6.4 (continued)

(1) Select the 100-μμF full-scale range.

(2) Select Q >30 and 10 kc/s, and turn the LOSS BALANCE control to indicate zero on the D scale.

(3) Connect a 100-μμF capacitor (see note below) across the DET and HI terminals; using the main BALANCE control, adjust for balance on the meter, using C26 if necessary, to obtain minimum reading.

(4) Switch to 1 kc/s and check that D=O (or nearly so) at this lower frequency. A small readjustment of the FINE BALANCE may be necessary.

The adjustment for the best balance conditions at both 1 and 10 kc/s will be found to be a compromise, but it can be considered as satisfactory if balance at both frequencies can be obtained within the first $2\frac{1}{2}$ meter scale divisions, and if the D setting for a well-defined balance is less than 0.001 at 1 kc/s. Should a large discrepancy arise in the D settings between 1 and 10 kc/s, then the test capacitor should be suspected.

(5) Repeat a similar procedure for the 1000-μμF full-scale range, using a 1000-μμF test capacitor and adjusting C25 if necessary.

(6) Repeat a similar procedure for the 0.01-μF full-scale range, using a 0.01-μF test capacitor, and adjusting C24 if necessary.

Note. The capacitors used for the above tests must be of high quality. Their accuracy is not so important, but dielectric loss must be as near to zero as possible. Polystyrene film types are recommended in preference to air dielectric types provided that the air is dry and the capacitor clean. Even the deposit left behind after handling will give rise to the discrepancy described in (4) above. It is a good precaution to dry out the test capacitors in a low temperature oven before using. An earthed (to the centre E terminal) guard ring around a test capacitor, particularly in the case of the 100-μμF one, can be used to prevent surface leakage.

TABLE 2

Valve Electrode Voltages

Valve	Anode		Cathode		Grid	
	Pin No.	Voltage	Pin No.	Voltage	Pin No.	Voltage
V1 (6X4)	1 and 6	310 a.c.	7	370		
V2 (12AT7)	1	150	3	1		
	6	270	8	3		
V3 (EF86)	6	90-250*	3	2-0*	1	60-100*
V4 (12AX7)	1	130	3	1		
	6	190	8	0.6		

All voltages shown are d.c. with respect to the chassis except for V1 anodes.

* Actual voltage depends upon the setting of the BALANCE control.

4.6.1 Oscillator Preset Resistors

Adjustments to the preset resistors, RV3 and RV4 in the 1-kc/s and 10-kc/s oscillator circuits are made before the instrument is dispatched. It is not expected that further adjustment will normally be needed. If, however, it is found necessary to reset these resistors, then the resonant frequencies of the preset tuned circuits including L1 and L2 in the detector-amplifier can be used as standards. The procedure is as follows :-

(1) Connect a 1000-ohm resistor between the DET terminal and the centre E terminal.

4.4 WORKING VOLTAGES

The voltages given in Tables 1 and 2 are for guidance when servicing the instrument and are representative of the readings to be expected if measurements are made with a meter having a resistance of 20,000 ohms per volt.

On individual instruments some variation in readings can be expected due to normal variations in valve performance and component values. Check that the mains input is adjusted to suit the supply voltage before carrying out any voltage checks on the instrument.

4.5 REPLACEMENT OF VALVES

A list of valves fitted, together with suitable alternative types, will be found in the SCHEDULE OF PARTS SUPPLIED Section of this handbook. It is recommended that faulty valves should preferably be replaced with a type originally supplied in the instrument. No special selection or aging is required.

4.6 ADJUSTMENT OF PRESET COMPONENTS

After removing the instrument from its case, it will be seen that all the main components are clearly marked, hence no difficulty will be experienced in identifying any of the preset controls for which adjustment procedure is described in the following sub-sections.

Note. In the event of any wiring changes, the value of C41 may need re-selecting in order to resonate L1, the 1 kc/s filter, (see Section 4.6.3).

3.2.5 Power Supplies

The two tapped primary windings of the mains transformer, T1, permit a series or series-parallel arrangement in order to cover the input ranges 100 to 130 volts and 200 to 250 volts at 40 to 60 c/s. Voltage adjustments are made by means of a plug-in type mains panel as described in Section 4.3.

The h.t. supply is derived from a full-wave rectifier V1 via resistance-capacitance smoothing. The heater of V1 is supplied separately from the secondary winding LT1, while secondary winding LT4 is common to the heaters of V2, V3 and V4. LT3/LT5 provides d.c. at two levels via the rectifier MR1, and LT2 provides the energizing source for the vibrator relay - these are switched into use when measuring resistance, as described in Section 3.2.2.

3.2.6 D.C. Choke Adaptor Type TM 6113

Referring to the Circuit Diagram, Fig. XC 31308, it will be seen that the external d.c. supply is applied across the winding of the inductor under test via coils L1 and L2. The tuned circuits which include L1 and L2 are tuned to resonance at 1 kc/s, and at this bridge frequency serve the purpose of significantly isolating the load due to the d.c. supply from the test terminals of the Bridge. The d.c. is prevented from flowing through the measuring bridge circuit by the presence of the capacitor C10.

To account for the variation in frequency between different instruments, the tuned circuit L1/C7 is made variable by means of the switch capacitors C1 to C6, and the trimmer capacitor, VC1. Fixed tuning only is employed for L2/C8, since this circuit only shunts the amplifier-detector input of the Bridge, and therefore does not affect the accuracy.

3.2.3 (continued)

Capacitance Bridge. When changing from inductance to capacitance measurement, the standard arm of the bridge is interchanged in position with the main balance arm by the contacts of the LCR switch.

As for inductance measurement, the arrangement of the standard arm will depend upon the loss in the component under test. A typical arrangement for the measurement of capacitance and dissipation factor (D or tan δ) is when the standard capacitance (capacitors C12 to C19 as described for the inductance bridge) is in series with the LOSS BALANCE variable resistor RV7. Range switching and main balancing adjustment remains the same as for inductance measurement.

3.2.4 Amplifier-Detector

This circuit (diagram Sheet 3) employs two valves, a pentode, V3, and a double triode, V4, in a circuit arrangement consisting of three stages of amplification, followed by a germanium diode detector MR2, feeding the balance meter and the a.g.c. line.

When resistance is measured, the out-of-balance d.c. voltage from the bridge is applied via a contact of the LCR switch wafer SBb and an R-C filter network to the vibrating contacts of the chopper relay RL. The R-C filter network affords smoothing to the out-of-balance bridge voltage and attenuates any supply-frequency hum pick-up on the test component. The vibrating contacts of the relay perform a chopping action at twice the supply frequency, thereby converting the d.c. into a.c. at approximately 100 c/s, which is then applied to the grid of V3 via R51 and C38.

The relay coil is energized by the secondary winding LT2 - the circuit to the coil being completed via the switch wafer SBh when the LCR switch is turned to either R or Rx10. The hum-bucking potentiometer RV2 (shown on Sheet 1) connected in parallel with LT2 and the relay coil, minimizes the effect of mains hum pick-up via the relay contacts.

3.2 CIRCUIT DESCRIPTION

3.2.1 Measuring Bridge A.C. Supply

The double triode valve V2 (Drawing No. XD 32020 Sheet 1) combines the functions of oscillator and amplifier for energizing the measuring bridge when switched for inductance or capacitance measurement.

Valve section V2a is connected as a phase-shift oscillator; switched ladder networks provide the necessary circuit constants for the maintenance of oscillations at 1 and 10 kc/s. The three-stage network, including the preset resistor RV3, controls the oscillation at 1 kc/s, and the 4-stage network which includes preset resistor RV4. controls the oscillation at 10 kc/s. The method of setting up the preset resistors RV3 and RV4 is described in Section 4.6.1.

Valve section V2b functions as an amplifier, receiving its input either from the grid circuit of V2a or from an external source via the EXT. OSC. socket, JKA. When the external oscillator supply is plugged in, the contacts of JKA automatically disconnect and earth the internal oscillator output.

Transformer T2 couples the output from the amplifier to the measuring bridge input; it is a step-down transformer of specialized design which affords efficient matching into the bridge impedance, and possesses the properties of low self-capacitance and small external magnetic field. Resistor R11, shunted across the primary winding of the transformer, minimizes the reaction on the oscillator due to changes in bridge impedance. The output from T2 is routed to the measuring bridge input via the LCR switch wafers SBd and SBf (Drawing No. XD 32020, Sheet 2), and its screen is permanently connected to the standard capacitance (C12 to C19).

3.2.2 Measuring Bridge D.C. Supply

The d.c. voltage required by the bridge when measuring resistance is obtained from the rectified outputs of secondary windings LT3 and LT5 on the mains transformer. When switched to R, the contact of the LCR switch wafer SBg selects LT3; the output is then applied to the bridge via the full-wave rectifier, MR2. When switched to Rx10, windings LT3 and LT5 are selected, thus providing increased voltage in order to retain bridge sensitivity for the higher resistance range.

2.7.1 (continued)

A suitable value, Rv, for an external Q potentiometer is given by

$$Rv = \frac{Q \text{ max}}{f} \times 1592 \text{ k}\Omega$$

where Q max = maximum expected Q of component,
f = test frequency in c/s.

The balance procedure is then normal except that the external Q potentiometer is used as well as the two internal controls, but the Q value can not be obtained from the reading on the dial. If this is required, set the LOSS BALANCE control to zero and rebalance using only the external Q potentiometer; then disconnect the potentiometer and measure its value, R.

$$Q = \frac{Rf}{1592}$$

where R is in kΩ and f in c/s.

High-dissipation capacitors such as electrolytics may require an external D control in order to obtain the more realistic series equivalent value of capacitance. 5 kΩ is suggested as a suitable value to cover all normal requirements. The dissipation factor is given by

$$D = \frac{Rf}{1592}$$

where R is in kΩ and f in c/s. The value of R is found in the same way as for Q measurement above.

2.6.3 Notes on Capacitive Loss Balancing *

The information given for inductive loss balancing in parts (1) to (3) of Section 2.5.4 applies equally for capacitors; however, since most capacitors have a dissipation factor of less than 0.03, measurement will generally be made at 1 kc/s using the $Q > 30$ range, in which case the D scale of the LOSS BALANCE dial is direct reading and the FINE Q control is inoperative.

The Bridge measures the resistive and capacitive components of a capacitor as a series network when the D-Q switch is set to $Q > 30$, and as a parallel network when set to Q = 0-30 or Q = 0-3. The equivalent parallel (Cp) and series (Cs) capacitances are related by the expressions

$$Cp = \frac{Cs}{1 + D^2}$$

$$Cs = Cp \frac{(1 + Q^2)}{Q^2}$$

Therefore, when using the 0-30 Q range to measure a lossy capacitor, the indicated parallel capacitance may be converted to the series form by multiplying by $(1 + Q^2)/Q^2$.

It is important to note the larger difference between Cs and Cp as the Q of the test component is reduced, viz :-

Q = 5	Cs = Cp + 4%
Q = 3	Cs = Cp + 11%
Q = 2	Cs = Cp + 25%

With electrolytic capacitors in particular, it is found that, provided that the Q is greater than 5, the results are fairly reliable, but as Q decreases, the interpretation of the measurement after applying the Cs/Cp relationship does not necessarily give results having any great degree of accuracy. They are particularly prone to be frequency dependent and, in practice, apparent error up to 50% can arise between their claimed value and the value measured on the Bridge, both of which may be correct; this confusion usually arises because such capacitors are commonly tested during manufacture at 50 or 60 c/s.

* See also Amendment Sheet No. 642/1.

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2.6.1 (continued)

If the meter reading decreases then reduce the range setting by one step and repeat (3) until the meter reading increases, showing that the correct range has been reached. If it still decreases when the bottom range is reached, then the capacitance value is less than 10 μμF.

(4) Having selected the correct range, start from the left-hand scale window and rotate the coarse BALANCE control clockwise (or counter-clockwise for values below 10 μμF) to obtain the lowest meter reading.

Final balance is achieved by adjusting the LOSS BALANCE and coarse BALANCE controls alternately until the lowest meter reading is obtained. Then adjust the LOSS BALANCE and fine BALANCE controls to obtain as near as possible a zero meter reading.

2.6.2 In-Situ Capacitance Measurement

Capacitors may be measured in situ, that is without disconnecting them from their associated circuit, provided the following precautions are observed.

(1) Neither the HI nor the DET terminal of the Bridge must be earthed. This means that, if one side of the capacitor is connected to an earthed chassis, then the chassis itself must be isolated from earth by disconnecting the power supply lead, etc.

(2) The capacitance between the leads may have to be considered, and subtracted if significant.

(3) Resistance between the HI terminal and earth may make loss balancing difficult and should therefore be kept above 5 MΩ.

(4) Capacitance between the HI terminal and earth results in an error of -1% per 1000 μμF.

(5) Interference picked up on the lead to the DET terminal may mask the balance point.

2.5.5 (continued)

If the Bridge frequency is further off tune than the limits of the Q TRIMMERS permit, then readjustment of the Q control on the Bridge will be necessary. In such circumstances the inductance measurement accuracy will not be seriously affected unless the Q control is grossly offset.

(4) Finally disconnect the inductor and connect the screened Lo lead from the Adaptor to the DET terminal on the Bridge.

Chokes may now be measured, with appropriate d.c. polarization, by connecting them across the Hi and Lo terminals on the Adaptor. The normal Bridge controls should be used without further readjustment of the Q TRIMMERS.

Accuracy

Without very careful precautions it is not easy to obtain consistently accurate measurements of the inductance of ordinary transformers and chokes with laminated cores. The reading of inductance will often be found to vary according to their position relative to earthed objects, mains power leads, etc. Movement of their leads can often change the answer. These effects are due to imperfections of ordinary alloys as a core material, and to stray capacitance between leads. The errors are, in general, proportional to inductance.

When measuring chokes in excess of about 20 henrys, slight residual coupling between the tuned circuits in the Adaptor may give rise to false balance. Careful arrangement and screening have reduced the largest error at 100 henrys to about 10%. This error reduces with reduced inductance to an error which normally does not exceed 3% at 20 henrys and below. Q accuracy, however, degenerates progressively above about 10 henrys - but this is a requirement that is seldom encountered.

2.5.4 (continued)

(c) Measurements at other frequencies

(using external oscillator and detector)
F = oscillator frequency in kc/s

D-Q switch position	LOSS BALANCE dial reading
Q = 0-30	Multiply Q scale by F.
Q > 30	Multiply D scale by F; $Q = \frac{1}{\text{D scale reading} \times F}$
Q = 0-3	Multiply Q scale by 10 F.

(4) Series or Parallel Values

The Bridge measures the inductive and resistive components of an inductance as a series network when the D-Q switch is set to Q = 0-30 or Q = 0-3, and as a parallel network when switched to Q > 30.

The equivalent series (L_s) or parallel (L_p) inductance are related by the expression

$$L_s = L_p \left(\frac{1}{1 + D^2} \right)$$

Therefore, when switched to Q > 30, the indicated parallel inductance can be converted to the more familiar series form by multiplying by $1/(1 + D^2)$. The difference is normally very small : about 1% for D = 0.1 (Q = 10) and 0.1% for D = 0.03 (Q = 33).

2.5.3 (continued)

Shunt capacitance however, due to the positioning of the components and the arrangement of the test leads, may lead to appreciable errors in measurement. Such errors, which will increase with frequency, can be minimized by careful positioning of the component, using short well-spaced leads and, whenever possible, supporting it on the insulated platform on top of the instrument.

Core Saturation

If the inductor is of such a type that its core may become easily saturated, it is advisable to use 10 kc/s and, if possible, to switch to the highest range that still covers the component value (by measuring a 10-mH inductor on the 10- to 100-mH range instead of the 0- to 10-mH range) thereby reducing the current through the inductor windings.

Note: Iron- or ferrite-cored inductors are particularly liable to pick up stray radiation which, applied to the bridge via the DET terminal, will tend to mask the balance point indication. To check for this effect, insert an unconnected telephone plug into the EXT. OSC. jack in order to switch off the internal oscillator. Any reading on the meter is now due to stray pick-up, and the inductor should be turned or repositioned to minimize the effect.

2.5.4 Notes on Inductive Loss Balancing

(1) Definitions

Q = magnification factor $= \frac{\omega L}{R} = \frac{X}{R}$

D = dissipation factor (or tan δ or loss tangent) $= \frac{1}{Q} = \frac{R}{X}$

$\cos \phi$ = power factor $= \frac{R}{\sqrt{X^2 + R^2}} = \frac{R}{Z}$

($\cos \phi \simeq D$ for values less than 0.1)

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2.5.2 (continued)

A recommended measurement procedure is detailed below; this gives an approximate first balance which is often within 10% - a great help in evaluating these difficult components.

(1) Set the controls as follows :-

LCR switch	:	L
D-Q switch	:	Q = 0-3
1 kc/s-10kc/s	:	10 kc/s
LOSS BALANCE control	:	Fully clockwise
FINE Q control	:	Mid-way
COARSE BALANCE control	:	0

First measure the approximate inductance as follows :-

(2) Turn the RANGE switch to its highest setting. Using rapid movements with the fine BALANCE control, search for a balance point, reducing the range a step at a time. (Ignore the slow recovery of the meter pointer due to the a.g.c. system.) Reduce the range by one step if the balance position is below 10 on the fine BALANCE dial.
Note: If the inductor Q is extremely low, the balance indication will be rather flat.

(3) Read the inductance value (using table 1 as a guide if necessary) from the fine BALANCE dial. This will only be an approximate value, although the sharper the balance indication the more accurate is the value obtained.

TABLE 1

Left-hand Scale Window Value	Fine BALANCE Range ~
10 H	1 H
1 H	100 mH
100 mH	10 mH
10 mH	1 mH
1 mH	100 µH
100 µH	10 µH
10 µH	1 µH

2.5 INDUCTANCE MEASUREMENT

When measuring inductance, the loss balance controls must be used to balance out the resistive component of the inductor. The loss balance dial is direct-reading at 1 kc/s only; readings on either scale must be multiplied by 10 when measuring at 10 kc/s, further details of which are given in Section 2.5.4. The main balance dial is direct reading at all frequencies.

Most audio and power-frequency inductors may be measured at 1 kc/s using the 0-30 Ω range as described in the general measuring procedure, Section 2.5.1.

For small low-Q inductors such as r.f. coils it is better to use 10 kc/s and the 0-3 Ω range in accordance with Section 2.5.2.

For large inductors with a low self-resonant frequency or small inductors with a saturable core, special precautions are described in Section 2.5.3.

2.5.1 General Procedure

(1) Set the controls as follows :-

LCR switch	:	L
D-Q switch	:	Ω = 0-30
1 kc/s - 10 kc/s switch	:	1 kc/s
LOSS BALANCE control	:	About 10
FINE Q control	:	Mid-way
FINE BALANCE control	:	Mid-way

(2) If the approximate inductance is known, set the RANGE switch so that the anticipated value lies above the left-hand scale window (except for values less than 10 μH) and carry on as in step (4).

If the inductance value is completely unknown, adjust the RANGE switch to its highest setting, and continue as follows :-

Extra copy of odds
These
P 19
ONLY
(old list)

last
copy —
make
more

2.7 USE OF EXTERNAL OSCILLATOR AND DETECTOR

For measurements at frequencies other than 1 or 10 kc/s the bridge can be energized by an external audio oscillator at frequencies down to about 50 c/s. When plugged into the EXT. OSC. jack the oscillator output should be between 1 and 2 volts; inserting the plug automatically switches off the internal oscillator.

The use of an external oscillator also necessitates the use of an external detector since the internal detector's frequency range is limited by filters to 1 and 10 kc/s only; these filters are automatically disconnected when a plug is inserted in the EXT. DET. jack. As the impedance ratios of the bridge favour high frequencies, harmonics in the oscillator input will be accentuated in the output to the detector, and this may necessitate the use of filters in the external detector circuit. This is particularly important below 200 c/s; at higher frequencies an oscilloscope may be used to observe the balance but below 200 c/s extra selectivity and extra gain will be found necessary.

Although the main BALANCE dial is direct reading at any frequency, the reading of the LOSS BALANCE dial must be multiplied by f/1000, where f = external oscillator frequency in c/s. If f is less than 1 kc/s, an external loss balance control may have to be added - see Section 2.7.1 below.

2.7.1 External D-Q Terminals *

These terminals, which are always linked for measurements at 1 or 10 kc/s, enable an external potentiometer to be connected in series with the LOSS BALANCE controls. This is only necessary in order to maintain continuous Q coverage when using an external bridge-energizing oscillator at frequencies below 1 kc/s.

For example, at 500 c/s the Q and D ranges are divided by 2, giving a total Q cover of only 0 to 15 and 60 to ∞; the external potentiometer is needed to bridge the gap.

* See also Amendment Sheet No. 642/1.

2.6.2 (continued)

To reduce the effects of (3) and (5) it may be worth using screened leads for the connections, the screens being joined to the E terminal. This will add to the effect of (4) and, if this is likely to be significant, the error incurred can be found by the following substitution method :-

After balance has been reached, note the capacitance reading; then, without disturbing the test arrangement, disconnect - without moving - the leads from the test terminals, and substitute a capacitor of similar value to the capacitor under test. This should be of small physical size, and connected directly to the test terminals. Measure its value accurately, and then, with this capacitor still connected, re-connect the lead to the HI terminal and note the percentage change in the measured value when the Bridge is adjusted for balance again. This percentage error should then be used to correct the original measurement.

For example :

Value obtained by in-situ measurement = 120 μμF

Value of substitution capacitor = 110 μμF

Value of substitution capacitor with lead reconnected = 99 μμF

Percentage change = $\frac{-(110-99)}{110}$ x 100% = -10%

Corrected value for in-situ measurement = 120 μμF + 10%
= 132 μμF

Avoiding the effects of (3) and (4) often leads to conflicting requirements, since the large mass of the capacitor (e.g. the chassis) increases the stray capacitance effect if connected to the HI terminal and may introduce pick-up if connected to the DET terminal. It is generally better to connect it to the HI terminal and correct for the error rather than try to eliminate the pick-up.

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2.6 CAPACITANCE MEASUREMENT

When measuring capacitance, the loss balance controls must be used to balance out the resistive component of the capacitor.

All capacitors may be measured at 1 kc/s, and most with the D-Q switch set to the Q > 30 range. The low value of Bridge voltage allows the measurement of electrolytic capacitors provided they have been formed and their Q is greater than 5.

Do not overlook stray capacitances (detailed in Sect. 2.6.2) or the fact that lead inductance may introduce errors when measuring large capacitance at the higher frequencies.

In-situ measurements can be made subject to some limitations - see Section 2.6.2.

2.6.1 General Procedure

(1) Set the controls as follows :-

LCR switch	:	C
D-Q switch	:	Q > 30 (or 0-30 for electrolytics)
1 kc/s - 10 kc/s switch	:	1 kc/s
LOSS BALANCE control	:	Mid-way
FINE Q control	:	Mid-way
FINE BALANCE control	:	Mid-way

(2) If the approximate capacitance is known, set the RANGE switch so that the anticipated value is above the left-hand BALANCE scale window (except for values less than 10 μμF), and carry on as in step (4).

If the capacitance value is completely unknown, then select the highest capacitance range and continue as follows :-

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

2.5.5 Using the D.C. Choke Adaptor Type TM 6113

This Adaptor is designed to operate at 1 kc/s but, in order to accommodate frequency variations between individual Bridges, one of the 'isolating' tuned circuits within the Adaptor is variable, and it is therefore left to the user to adjust the Q TRIMMERS (switch and variable capacitor) to match the frequency of the Bridge in use. Once set, there is no need to make any further adjustments to these controls unless the Adaptor is used on a different Bridge.

The Q TRIMMERS are so called because their correct adjustment is essential if accurate Q readings are to be obtained.

When using the Adaptor, which is connected to the Bridge by means of permanently attached leads, d.c. up to 200 mA from an external source may be passed through the windings of the inductor under test while the measurement is being made.

To measure an inductor in this way (in the range 100 mH to 100 henrys), proceed as follows :-

(1) With the Adaptor disconnected, measure an inductor on the Bridge at 1 kc/s, note the control settings, and leave the inductor in place. If the balance indication is vague, this may be due to interference picked up by the inductor - see Section 2.5.3.

(2) Join the E terminal on the Adaptor to the E terminal on the Bridge, or a convenient place on the case.

(3) Join the brown (Hi) Adaptor lead to the HI terminal on the Bridge. This will usually cause a change in balance as indicated on the meter. Minimize this change by operating the Q TRIMMERS. A small adjustment to the fine BALANCE will also be necessary; if this is insufficient, move the coarse BALANCE by one step and readjust the fine BALANCE.

2.5.4 (continued)

(2) Fine Ω Control

This is in circuit on the 0-3 and 0-30 Ω ranges, but not on the Ω > 30 range. Since its range is only 0.06 Ω at 1 kc/s and 0.6 Ω at 10 kc/s, it is only effective towards the lower end of the LOSS BALANCE range and has a negligible effect on the dial reading accuracy.

(3) LOSS BALANCE Dial Reading

The LOSS BALANCE dial indicates either Ω or D depending on the Ω range selected. This is shown in the following tables together with the scale multiplying factors appropriate to the bridge operating frequency.

(a) Measurements at 1 kc/s

D-Ω Switch position	LOSS BALANCE dial reading	Ω range
Ω = 0-30	Ω scale is direct reading.	0-30
Ω > 30	D scale is direct reading; $\Omega = \frac{1}{D}$	30-∞
Ω = 0-3	Uncalibrated, but dividing the Ω scale reading by 10 gives a fair approximation.	0-3

(b) Measurements at 10 kc/s

D-Ω Switch position	LOSS BALANCE dial reading	Ω range
Ω = 0-30	Multiply Ω scale by 10.	0-300
Ω > 30	Multiply D scale by 10; $\Omega = \frac{1}{\text{D scale reading} \times 10}$	3-∞
Ω = 0-3	Ω scale is direct reading.	0-30

2.5.2 (continued)

To measure the coil accurately, proceed as follows :-

(4) Set the RANGE and coarse BALANCE controls to indicate the approximate value obtained above, and re-balance the bridge using the LOSS BALANCE controls to obtain the lowest meter reading.

(5) Offset the coarse BALANCE control a step at a time (usually counter-clockwise), re-balancing with the LOSS BALANCE controls to obtain as near as possible a zero reading. Use the FINE Q control if the loss adjustment becomes critical.

Do not stop at the first lowest reading, but continue to adjust, ultimately using the fine BALANCE and FINE Q controls alternately to obtain a zero reading - or at least within one or two divisions - on the meter scale.

2.5.3 Measuring Iron-Cored Inductors

To avoid errors in measurement, inductors having a low self-resonant frequency should not be tested at 10 kc/s. If their self-resonant frequency is lower than about 5 kc/s, then test results even at 1 kc/s will be in error - inductance will appear high, and magnification low. It will be found that 1 henry is the practical upper limit for measurements at 10 kc/s.

These errors will increase rapidly as the self-resonant frequency of the inductor approaches the test frequency and it is, of course, impossible to measure an inductor which resonates below 1 kc/s, since such a component will exhibit capacitive reactance. This effective capacitance may be measured on the bridge, but it will appear to have a poor dissipation factor. The inherent capacitance of the bridge at the test terminals is low - approximately 0.08 μμF - and will contribute little to lowering the self-resonant frequency of the component.

2.5.1 (continued)

(3) Turn the coarse BALANCE control so that the blue pointer is across the left-hand scale window; then turn the control counter-clockwise, noting the meter indication.

If the meter reading decreases, then reduce the RANGE setting by one step and repeat (3) until the meter reading increases, showing that the correct range has been reached. If the meter reading continues to decrease after the bottom range has been reached, then the inductance value is less than 10 μH.

(4) Having selected the correct range, start from the left-hand scale window and rotate the coarse BALANCE control clockwise (or counter-clockwise if the value is below 10 μH) to obtain a minimum meter reading. It helps if this is done fairly quickly since, until the Q setting is approximately correct, the balance indication will not be sharp. Therefore, it is best to adjust the LOSS BALANCE and the coarse BALANCE controls together for a sharp null.

Finally obtain as near as possible a zero meter reading by adjustment of the fine BALANCE control together with the LOSS BALANCE (and FINE Q if the loss adjustment is critical).

2.5.2 Measuring Low Inductance (R.F. Coils)

Small inductors - for example, r.f. coils - are difficult to measure on any audio frequency bridge because of their low Q at a test frequency which may be many thousands of times less than their operating frequency. Such inductors, being predominantly resistive at a.f., require a more exacting measurement procedure involving two separate balancing operations before a satisfactory final balance indication can be obtained.

The interdependence between the BALANCE and LOSS BALANCE controls becomes increasingly apparent as the value of Q decreases. It is for this reason that measurements should preferably be made at 10 kc/s since the Q appears to be 10 times greater at this frequency.

2.4.1 Measuring Low-Wattage Resistors

On the lower ranges, the effect of the 4 volts e.m.f. at the test terminals may have to be considered when measuring low-wattage resistors. The voltage across the resistor when connected to the DET and HI terminals will be less than the open-circuit e.m.f., and the resultant dissipation may be estimated from the following table.

Test Resistor ohms	Dissipation watts
0.5	0.1
1	0.175
5	0.5
20	0.52
50	0.25
100	0.175
500	0.035

When it is considered that even this low value of dissipation is too great for the particular test conditions, the test resistor should be placed in series with a resistor of known value as shown in the example below.

To measure a 75-ohm resistor rated at 0.1 watt :-

(1) Select a 680-ohm resistor of ample rating, and measure its value accurately; e.g., 676.4 ohms.

(2) Add the unknown resistor in series with the 676.4 ohm resistor and measure the total value; e.g., 750.3 ohms.

Difference : 73.9 ohms.
Dissipation : 0.0016 watt.

2.2 (continued)

The value of a component is most easily found by first noting the reading of the outer scale followed by the reading of the inner scale, and then putting in the decimal point by referring to the figure displayed in the nearest scale window. Typical examples are shown below :-

Range:	10 Ω	1000 kΩ	0.1 μF	100 μH
Outer dial:	08--	63--	104--	99--
Inner dial:	43	08	10	102
Value:	0.843 Ω	630.8 kΩ	0.10410 μF	100.02 μH

2.3 CONNECTING THE COMPONENT

Connect the component between the HI and DET terminals, using short leads where possible. Small components can often be directly supported by the test terminals or laid on the insulated component platform. Note the following precautions :-

(a) Impedance between the HI side of the component and earth shunts the 'balance' arm of the bridge and may result in an inaccurate reading.

(b) Stray pick-up on the lead to the DET terminal is applied to the input of the bridge detector and may result in difficulty in obtaining a clear balance indication. Using a screened lead, with the screen connected to the E terminal, helps to avoid this effect.

(c) The presence of an earth on either side of the component will short-circuit the bridge and make measurement impossible.

(d) The bridge energizing voltages appearing at the test terminals (see Data Summary) are sufficiently small to cause little risk of damage to the component or shock to the operator. The a.c. terminal voltage variations when measuring L or C are shown on drwg. no. XD 30557, at the end of the handbook.

1 INTRODUCTION

TF 1313 is a general-purpose impedance bridge with quarter per cent measurement accuracy over a wide range of inductance, capacitance, and resistance. It offers exceptional discrimination and resettability, wide-range loss balancing, and facilities for using an external oscillator and detector.

The single direct-reading dial used for L, C, and R measurements has coarse and fine concentric controls; the coarse one moves in 1% steps and the fine gives continuously variable interpolation between steps. Its meter gives a clear indication of the direction of the balance point even when far off-balance, bringing speed and simplicity to measurements of completely unknown components. An external audio oscillator can be plugged in where L and C measurements are required at frequencies other than the internal 1 and 10 kc/s; and the detector output is available externally to allow an oscilloscope or headphones to be used for balance indication.

This bridge can be used for precision evaluation of resistance capacitance and inductance, for measuring dissipation factor of capacitors and Q of inductors, and for quickly identifying unknown components. Measurements on high-loss components are made easier by the low-Q range of the loss balance control and the relative independence between the adjustment of the main and loss balance controls. Its high discrimination and resettability make it particularly suitable for comparative measurements such as checking the difference between an unknown and a standard component. Measurements on inductors carrying a d. c. current can be made by using Adaptor Type TM 6113, which is available as an optional accessory.

RESIDUALS (approximate):	Inductance :	0.05 μH.
	Capacitance :	0.08 μμF.
	Resistance :	0.001 ohm.

BRIDGE ENERGIZING SOURCE

L and C:	Internal 1- and 10-kc/s oscillator; fixed output level between 250 and 750 mV. External audio oscillator may be used instead.
R:	Internal d.c. supply, nominally 4 volts; nominally 22 volts on highest range.

POWER SUPPLY: 200 to 250 volts and 100 to 130 volts, 40 to 60 c/s, 25 watts.

DIMENSIONS & WEIGHT:

Height	Width	Depth	Weight
$11\frac{1}{2}$ in (30 cm)	$19\frac{1}{2}$ in (50 cm)	10 in (26 cm)	27 lb (12.5 kg)

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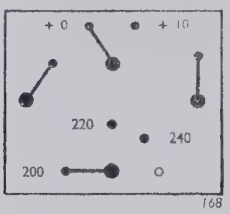
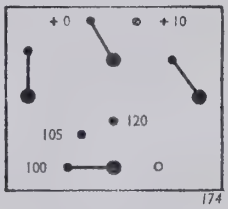
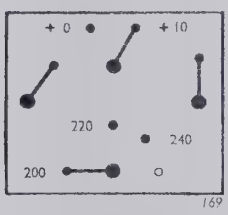
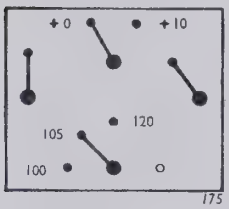
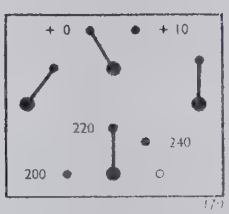
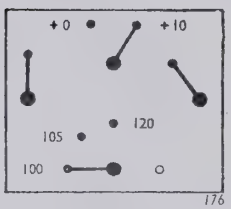
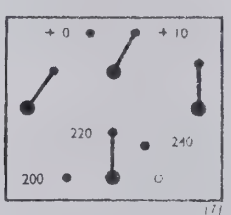
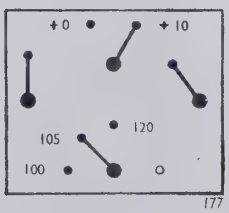
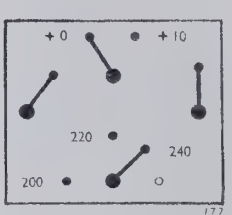
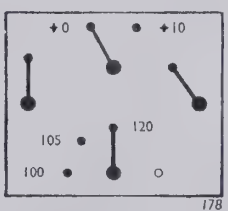
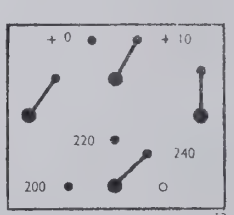
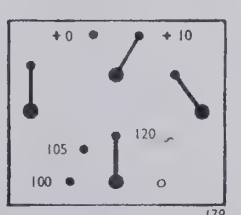
DRAWINGS	Ref. No.
SUPPLY VOLTAGE PLUG SETTINGS	Following p 27
FUNCTION DIAGRAM	XD 35166
CHARTS OF TEST TERMINAL VOLTAGES AT BALANCE	XD 30557
CIRCUIT DIAGRAMS ..... (3 sheets)..	XD 32020
D.C. CHOKE ADAPTOR CIRCUIT DIAGRAM	XC 31308

SUPPLY VOLTAGE PANEL

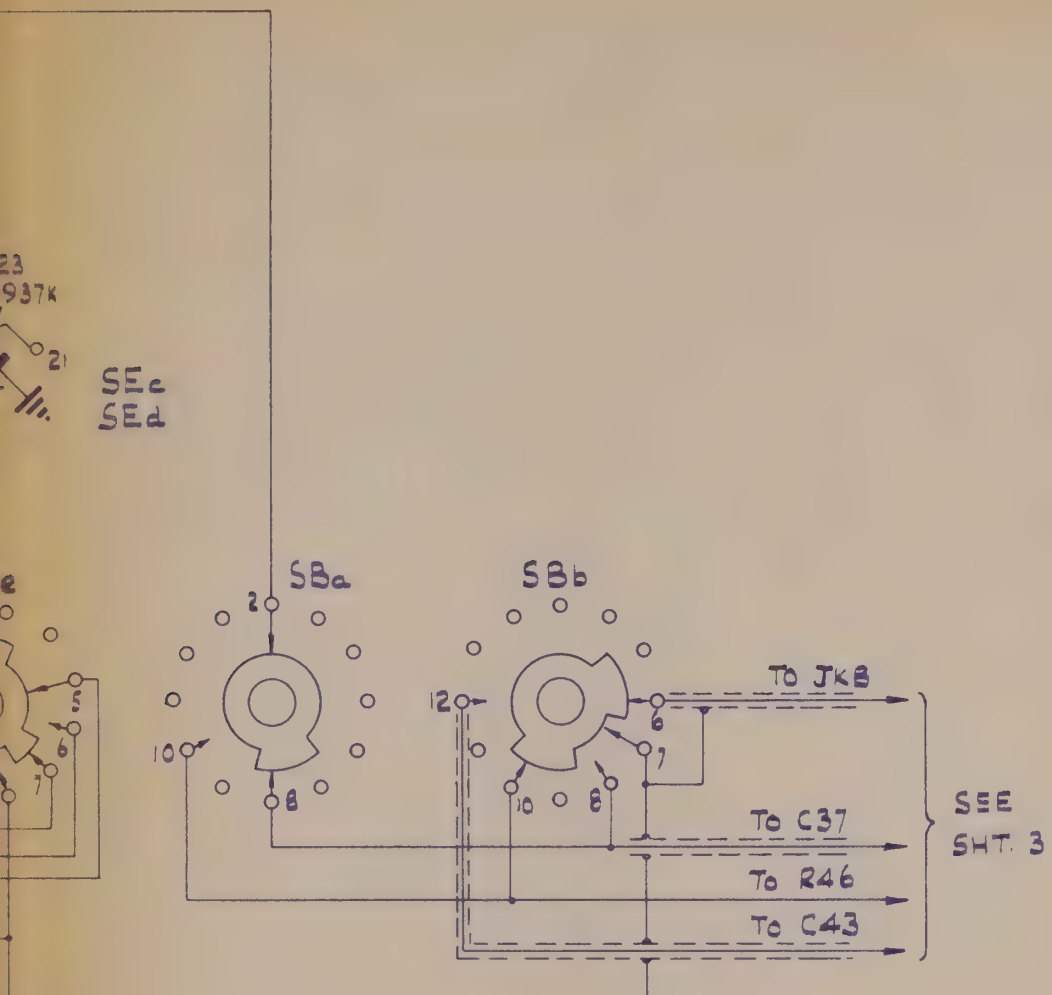
Masking plate and links must be positioned according to supply voltage, as shown:—

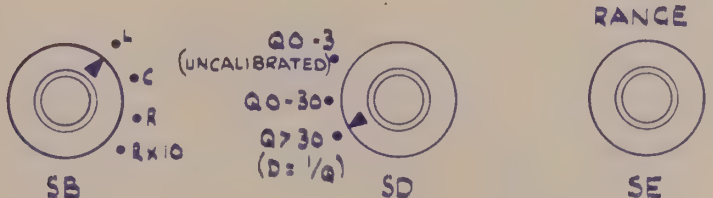
200-250 volts a.c. SUPPLY	LINKS		LINKS	100-130 volts a.c. SUPPLY
200 V				**100 V**
210 V				**105 V**
220 V		To change voltage range, remove all links and reverse masking plate		**110 V**
230 V				**115 V**
240 V				**120 V**
250 V				**130 V**

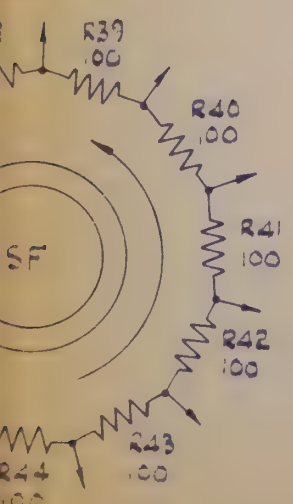
SUPPLY VOLTAGE PLUG SETTINGS

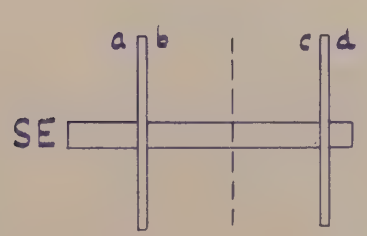
C.P. 5m. 12/60

M.I. LTD.

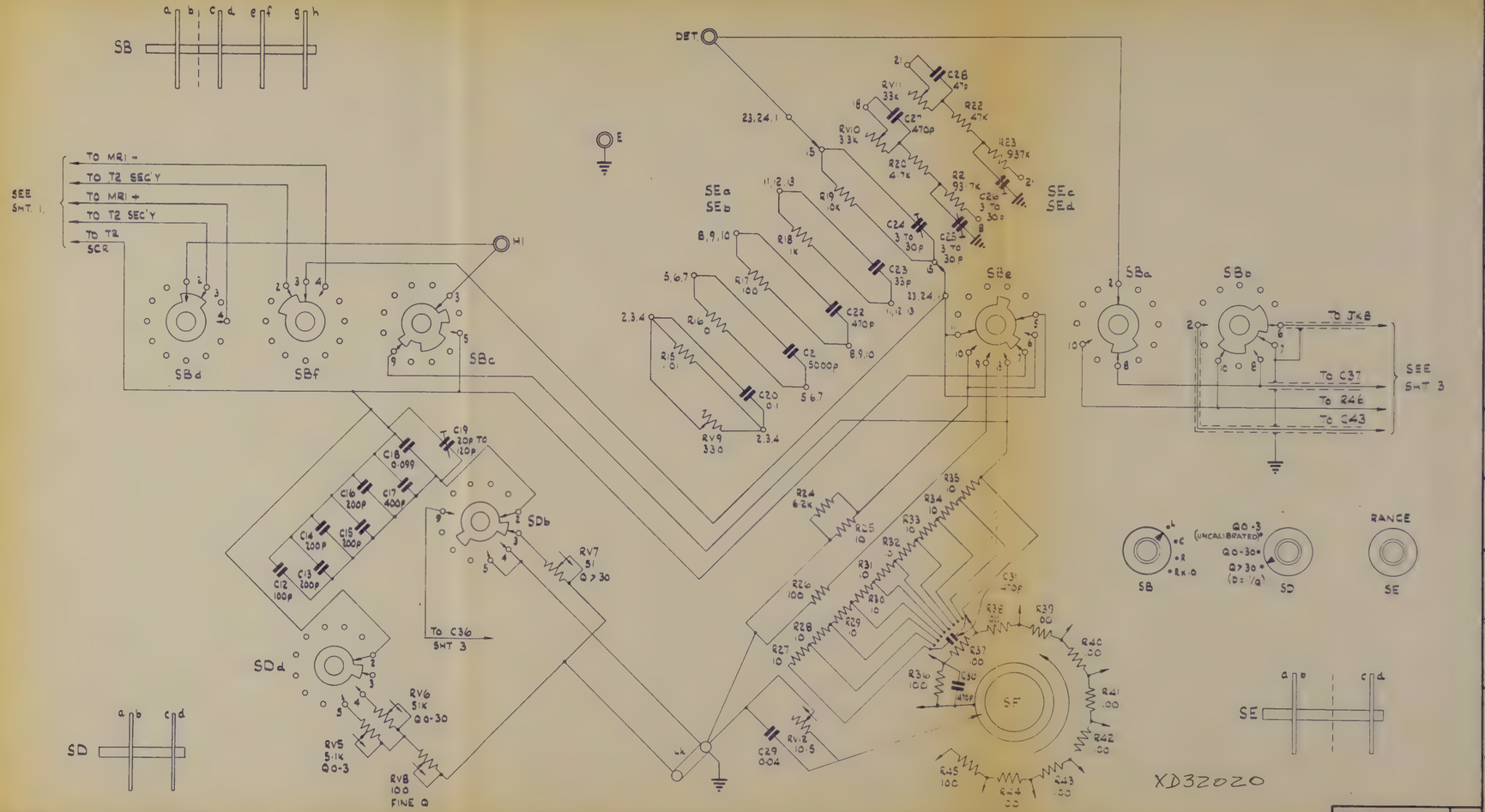

SEc
SEd
SBa
SBb
2
10
8
12
10
8
6
7
To JkB
To C37
To R46
To C43
SEE
SHT. 3


L
C
R
Rx10
SB
Q0-3
(UNCALIBRATED)
Q0-30
Q7-30
(D=1/Q)
SD
RANGE
SE


R39
100
R40
100
R41
100
R42
100
R43
100
SF

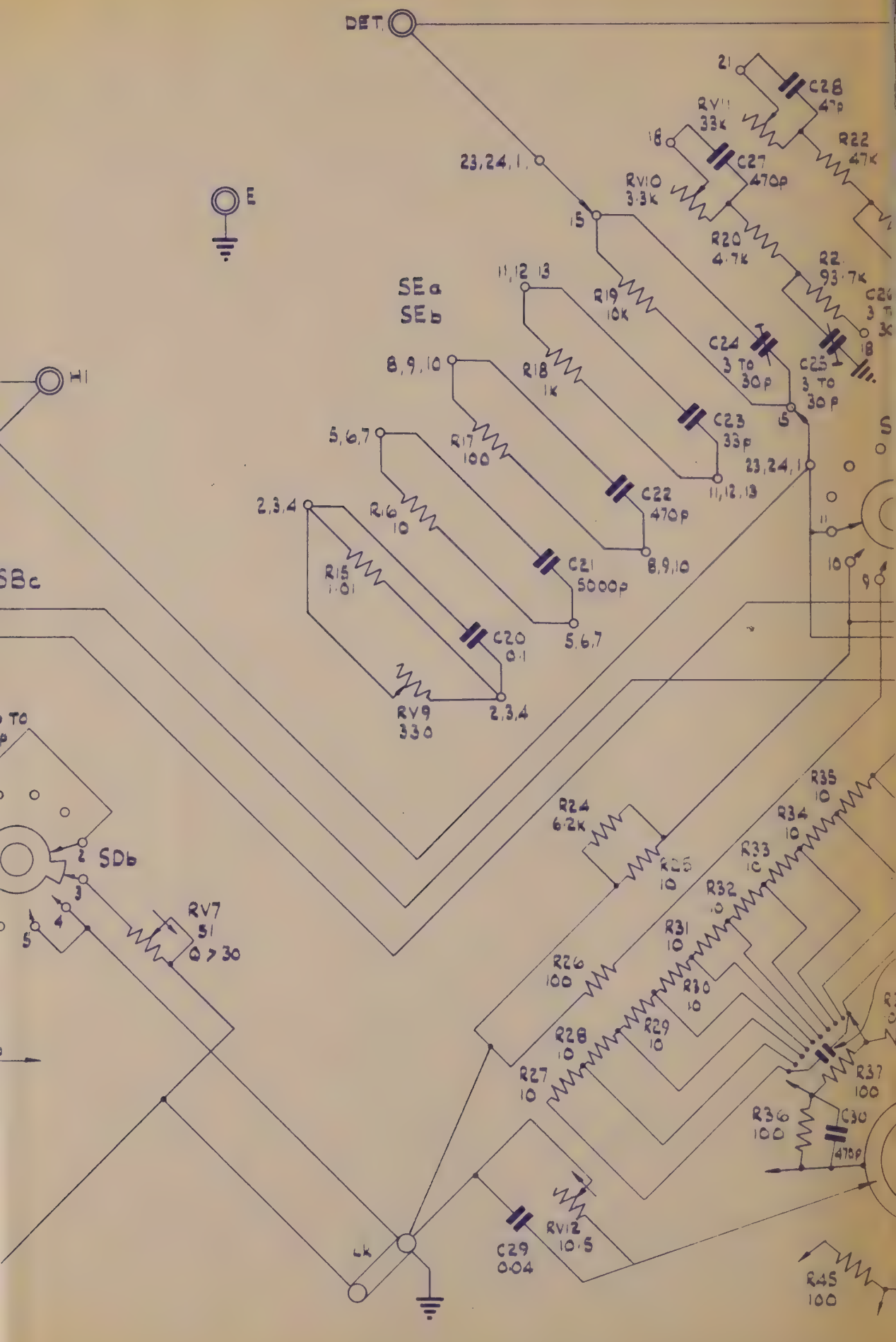

a
b
c
d
SE

XD32020

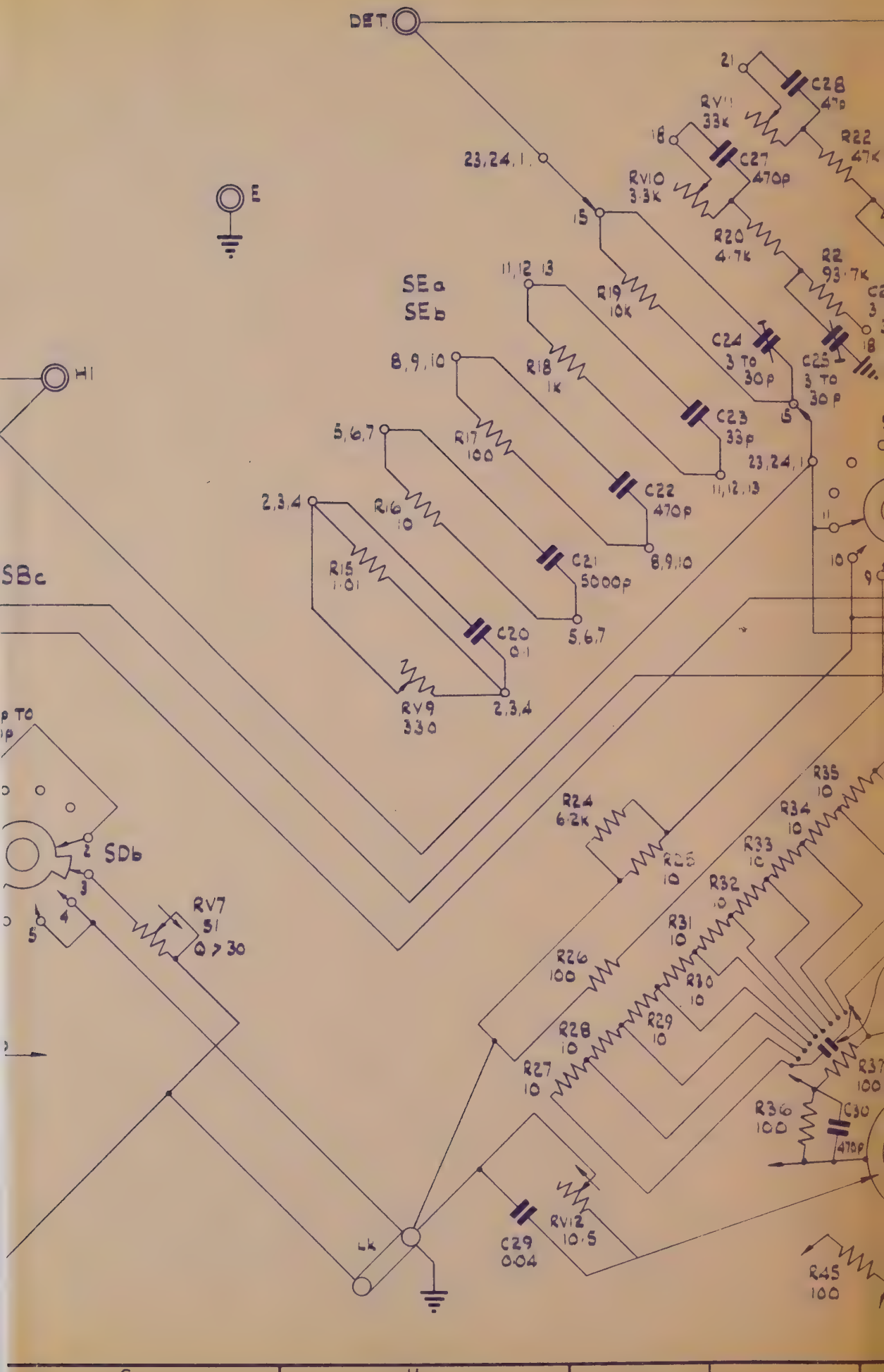


TITLE	BRIDGE						
DRAWN	DATE	CHK'D.	APP'D.	TR'C'D.	ASSEMBLY	STOCK LIST	DRAWING NUMBER
L.V. UNWIN	22-2-60		E.C.	E.M.T.	TE 32000	TF1313	XD32020
MARCONI INSTRUMENTS LTD.							SHEET 2 OF 3 SHEETS

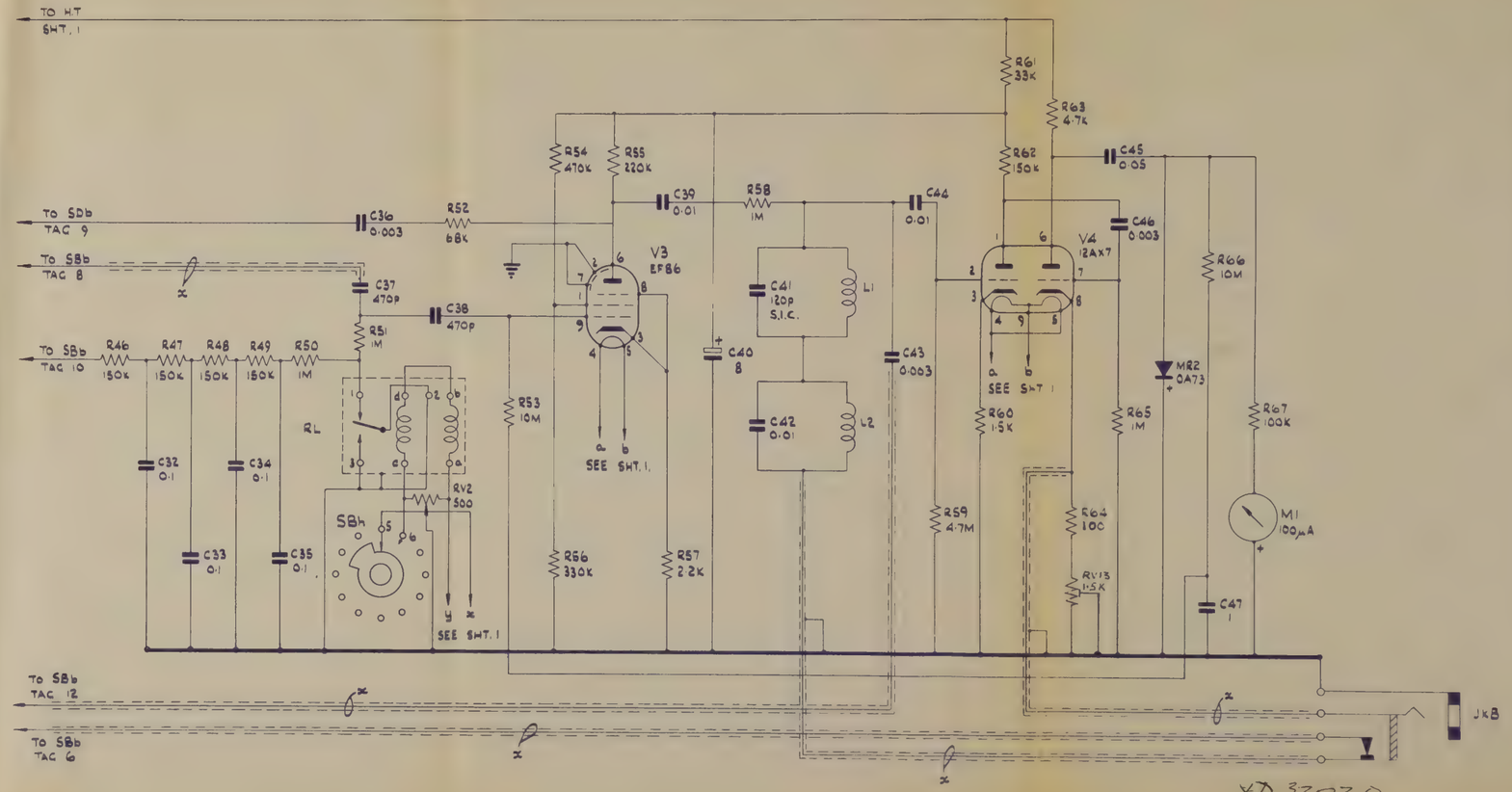
XD 32020


DET
E
H1
SEa
SEb
SBc
SDb
21
C28
47p
RV11
33k
18
C27
470p
R22
47k
23,24,1
RV10
3·3k
15
R20
4·7k
R21
93·7k
C26
3 TO
30p
18
11,12 13
R19
10k
C24
3 TO
30p
C25
3 TO
30p
8,9,10
R18
1k
C23
33p
5
5,6,7
R17
100
23,24,1
11,12,13
C22
470p
2,3,4
R16
10
11
10
9
R15
1·01
C21
5000p
8,9,10
C20
0·1
5,6,7
RV9
330
2,3,4
TO
p
2
3
4
5
RV7
51
Ω > 30
R24
6·2k
R25
10
R35
10
R34
10
R33
10
R32
10
R31
10
R26
100
R30
10
R29
10
R28
10
R27
10
R37
100
R36
100
C30
470p
4k
C29
0·04
RV12
10·5
R45
100
G
H
J

SI SMITH
MARCONI
INST.


DET.
E
H1
SEa
SEb
SBc
SDb
21
C28
47p
RV11
33k
18
C27
470p
R22
47K
23,24,1
RV10
3·3K
15
R20
4·7K
R2
93·7K
11,12,13
R19
10K
C24
3 TO
30p
C25
3 TO
30p
8,9,10
R18
1K
C23
33p
5,6,7
R17
100
C22
470p
2,3,4
R16
10
C21
5000p
R15
1·01
C20
0·1
RV9
330
RV7
51
Q > 30
R24
6·2K
R25
10
R35
10
R34
10
R33
10
R32
10
R31
10
R26
100
R30
10
R29
10
R28
10
R27
10
R37
100
R36
100
C30
470p
RV12
10·5
C29
0·04
R45
100
G
H
J

NOTE :- WIRING IN MINIATURE CABLE Nº 1C SHOWN THUS :- ═══x



XD 32020

TITLE	AMPLIFIER / DETECTOR						
DRAWN	DATE	CHKD.	APPD.	TRCD.	ASSEMBLY	STOCK LIST	DRAWING NUMBER
L.V. UNWIN	24-2-60		E.C.	E.M.T	TE 32000	TF1313	XD32020
MARCONI INSTRUMENTS LTD.							SHEET 3 OF 3 SHEETS

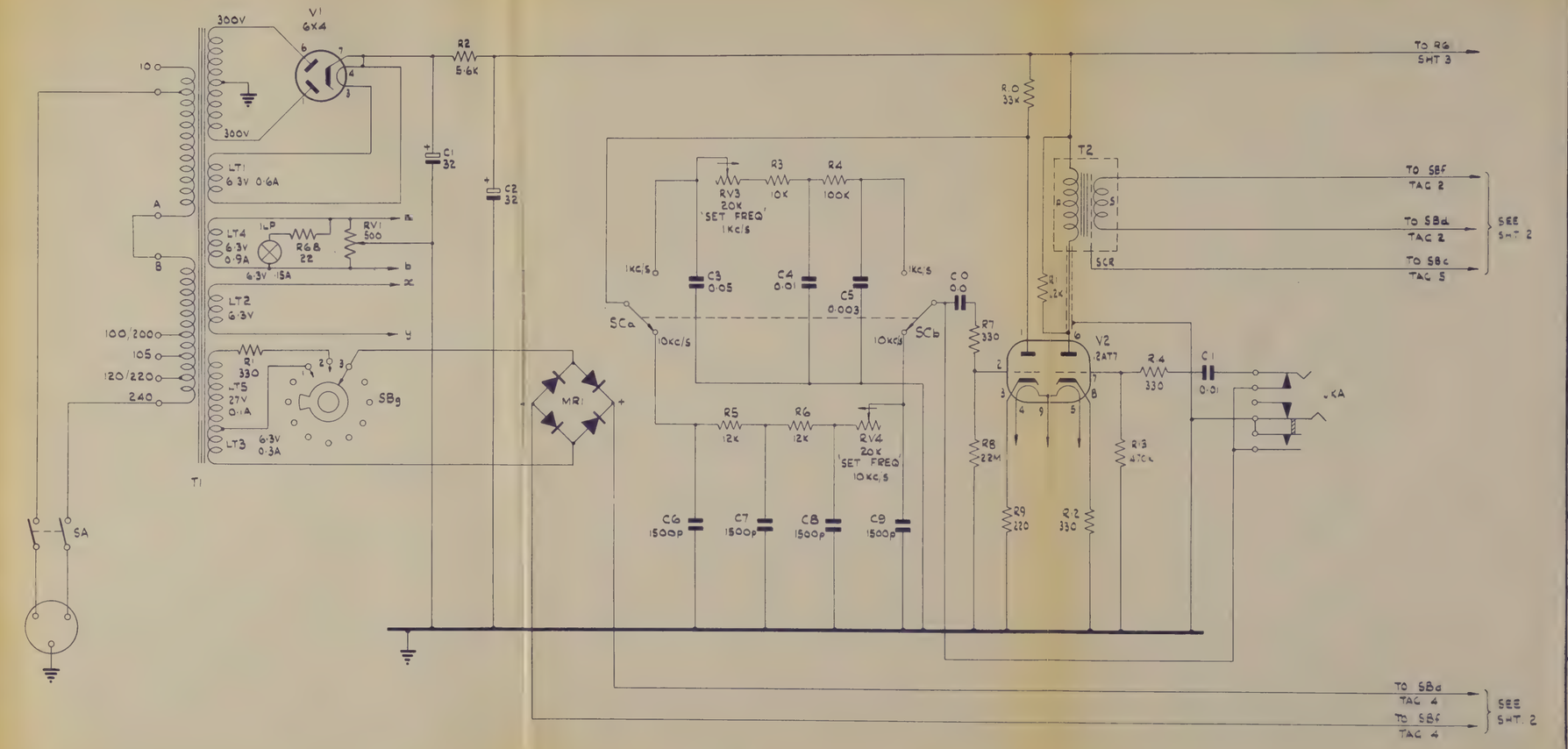
XD 32020

M

XD 32020

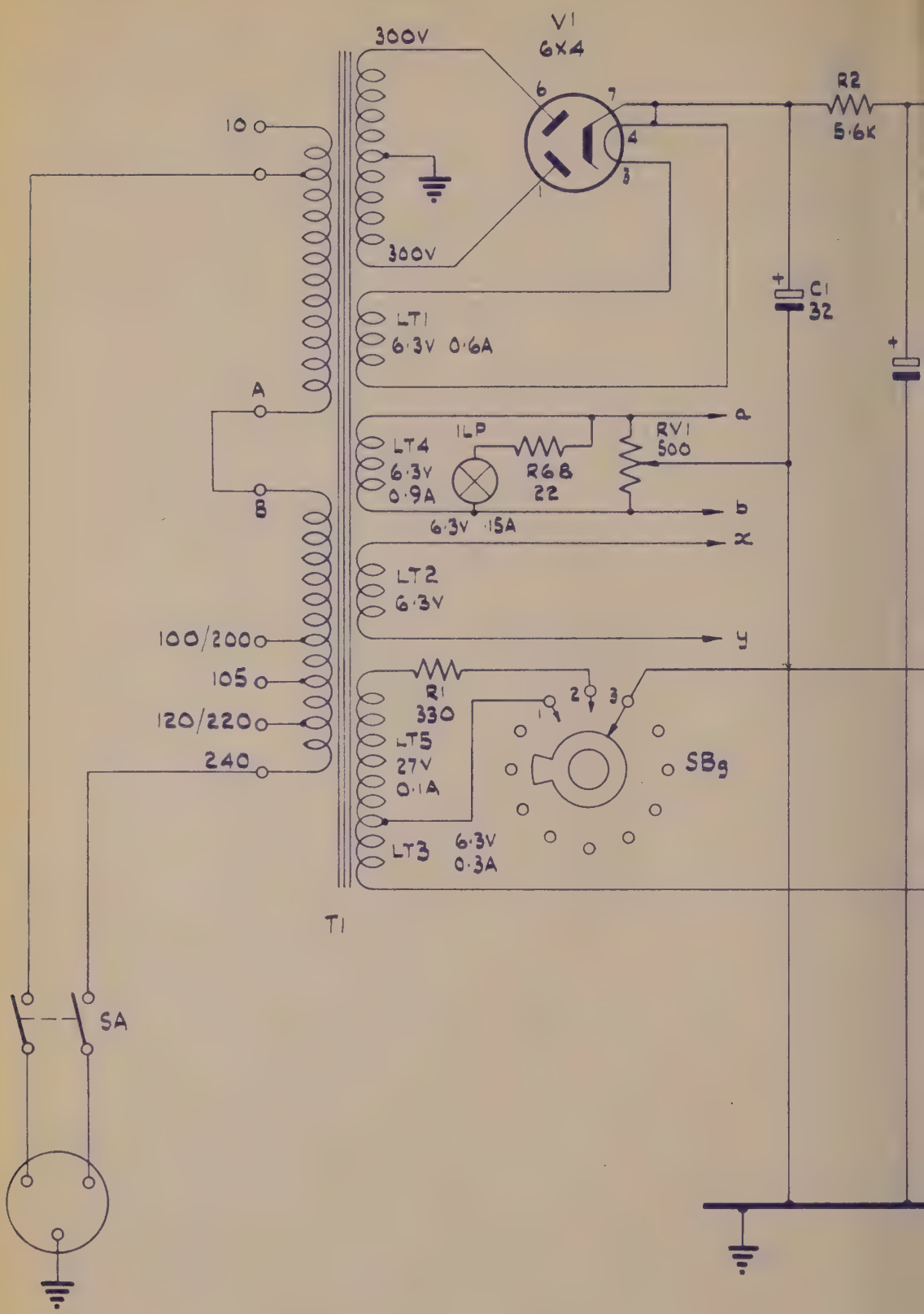
M

XD 32020



TITLE							
POWER SUPPLY & OSCILLATOR							
DRAWN	DATE	CHKD.	APPD.	TRC'D.	ASSEMBLY	STOCK LIST	DRAWING NUMBER
L.V. UNWIN	10-2-60	[signature]	E.C.	E.M.T.	TE 32000	TF1313	XD32020
MARCONI INSTRUMENTS LTD.							SHEET 1 OF 3 SHEETS

XD 32020

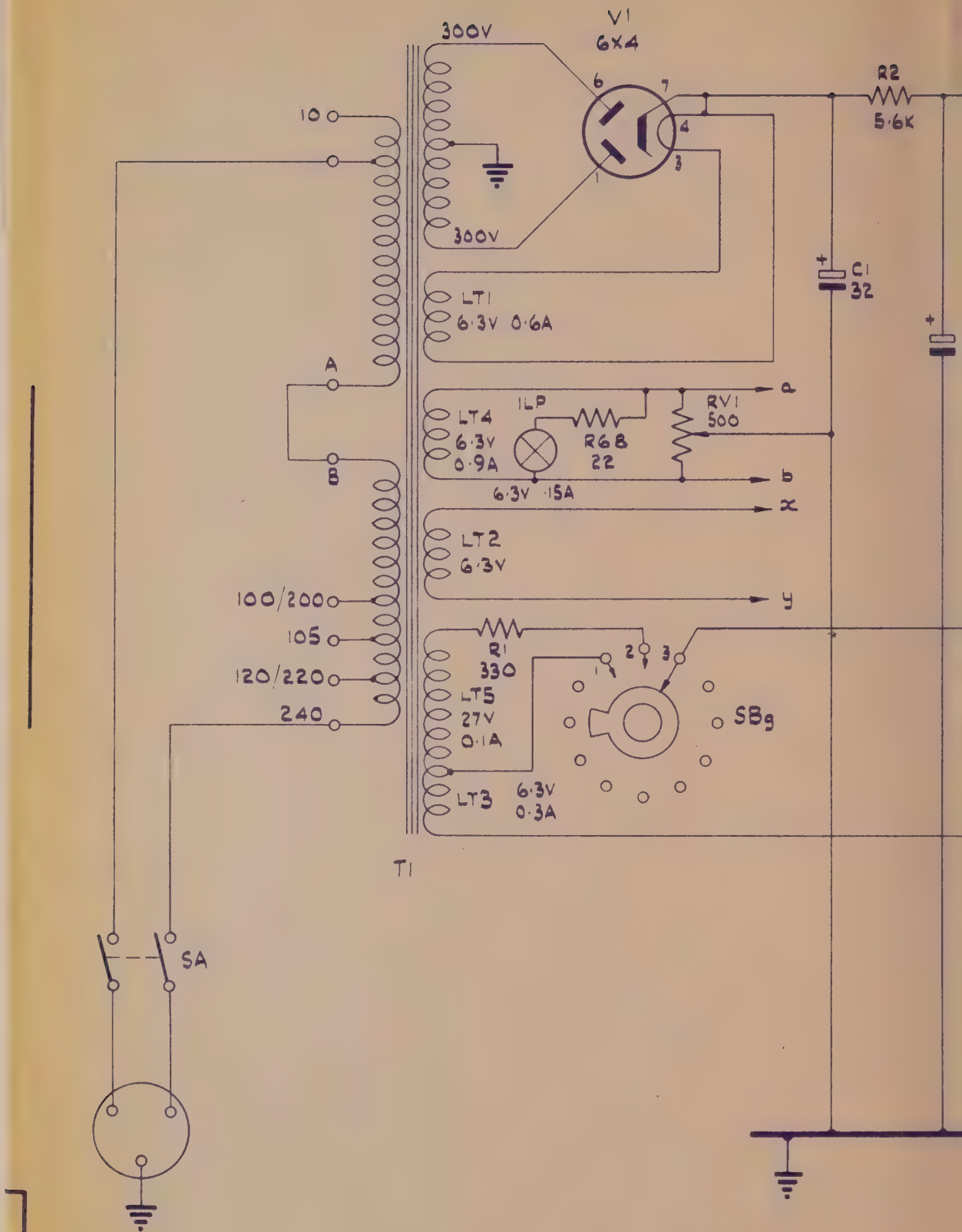

V1
6X4
300V
300V
10
A
B
100/200
105
120/220
240
LT1
6·3V 0·6A
LT4
6·3V
0·9A
ILP
R68
22
6·3V ·15A
RV1
500
a
b
x
y
LT2
6·3V
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
SBg
T1
SA
R2
5·6K
C1
32

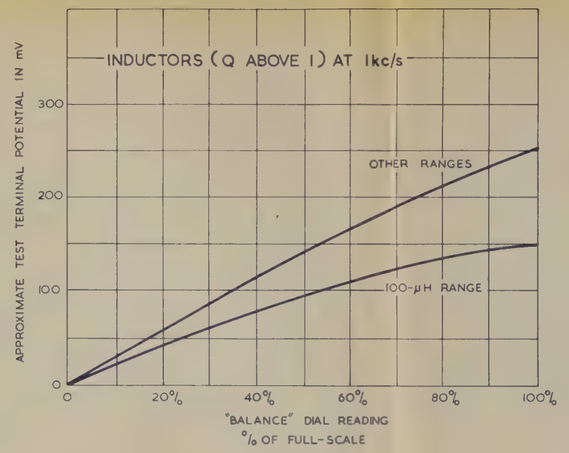
CHARTS OF TEST TERMINAL VOLTAGE AT BALANCE

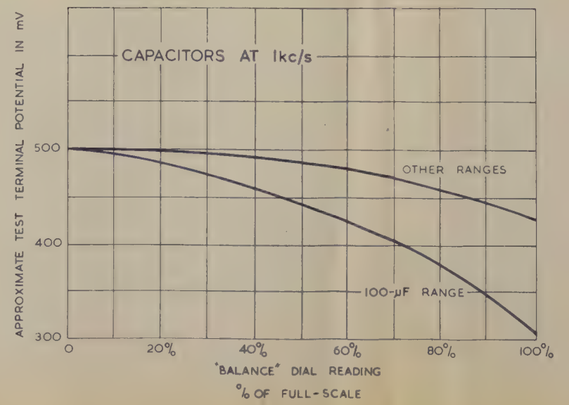
DATE	CHKD	APPD.	TRC.D.	ASSEMBLY	STOCK LIST	DRAWING NUMBER
25-7-59			E.M.T.		TF 868 B TF 1313	XD 30557

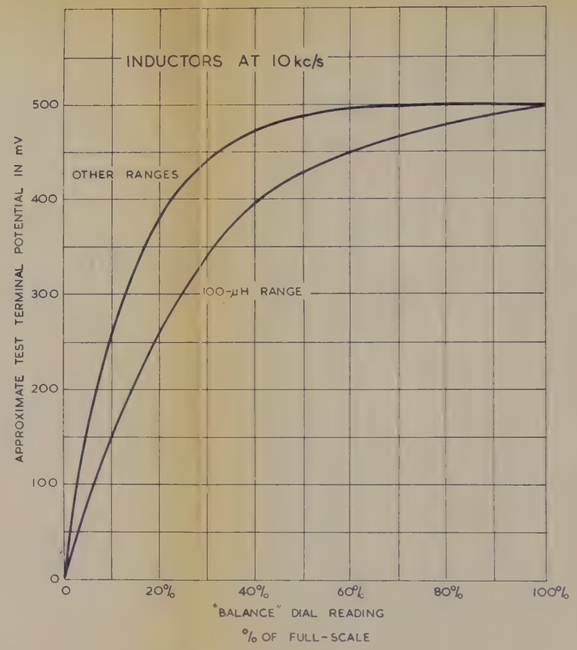
MARCONI INSTRUMENTS LTD. SHEET OF SHEETS

A B C


V1
6X4
300V
300V
10
A
B
100/200
105
120/220
240
LT1
6·3V 0·6A
LT4
6·3V
0·9A
ILP
R68
22
6·3V ·15A
RV1
500
a
b
x
LT2
6·3V
y
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
SBg
T1
SA
R2
5·6K
C1
32





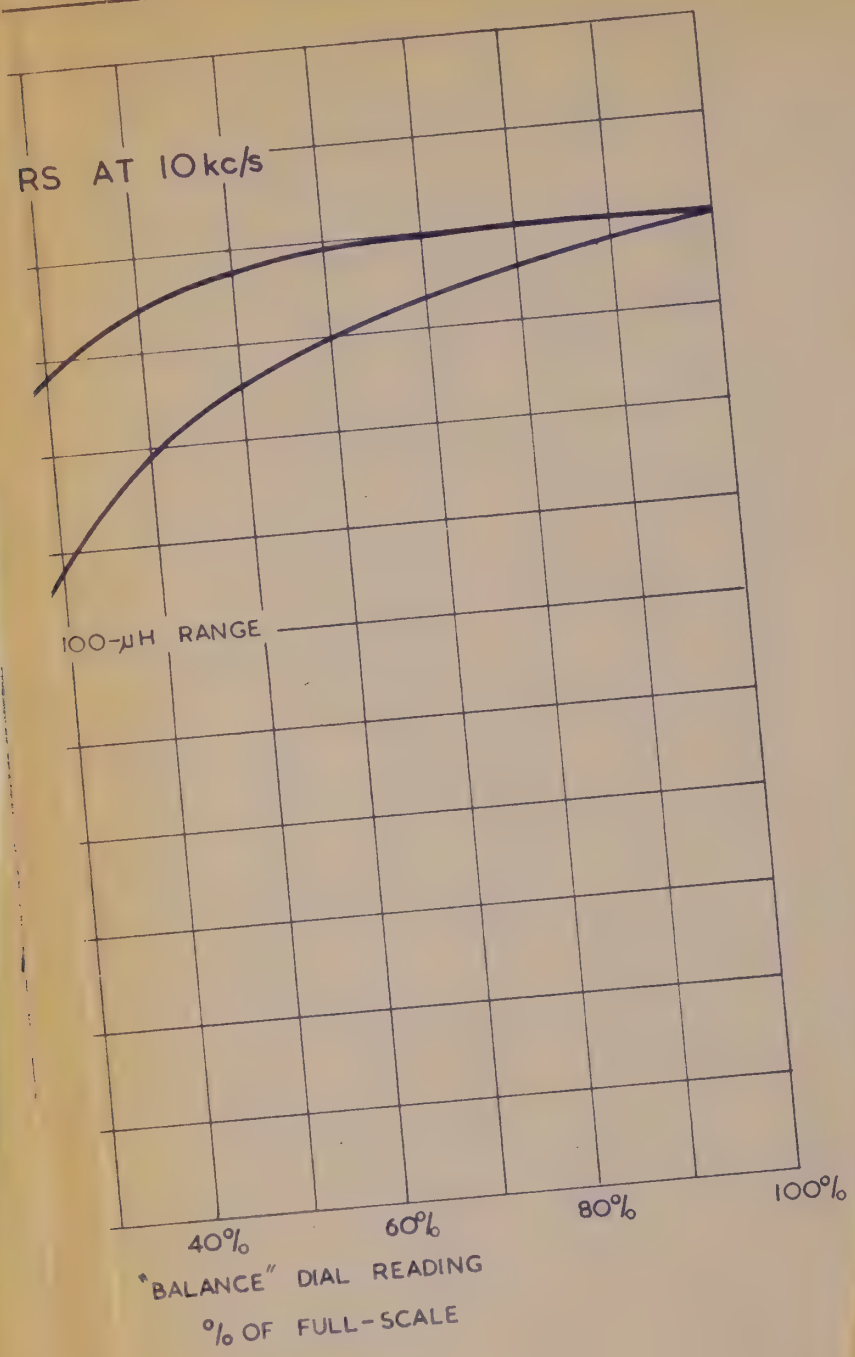


CHARTS OF TEST TERMINAL VOLTAGE AT BALANCE

XD 30557

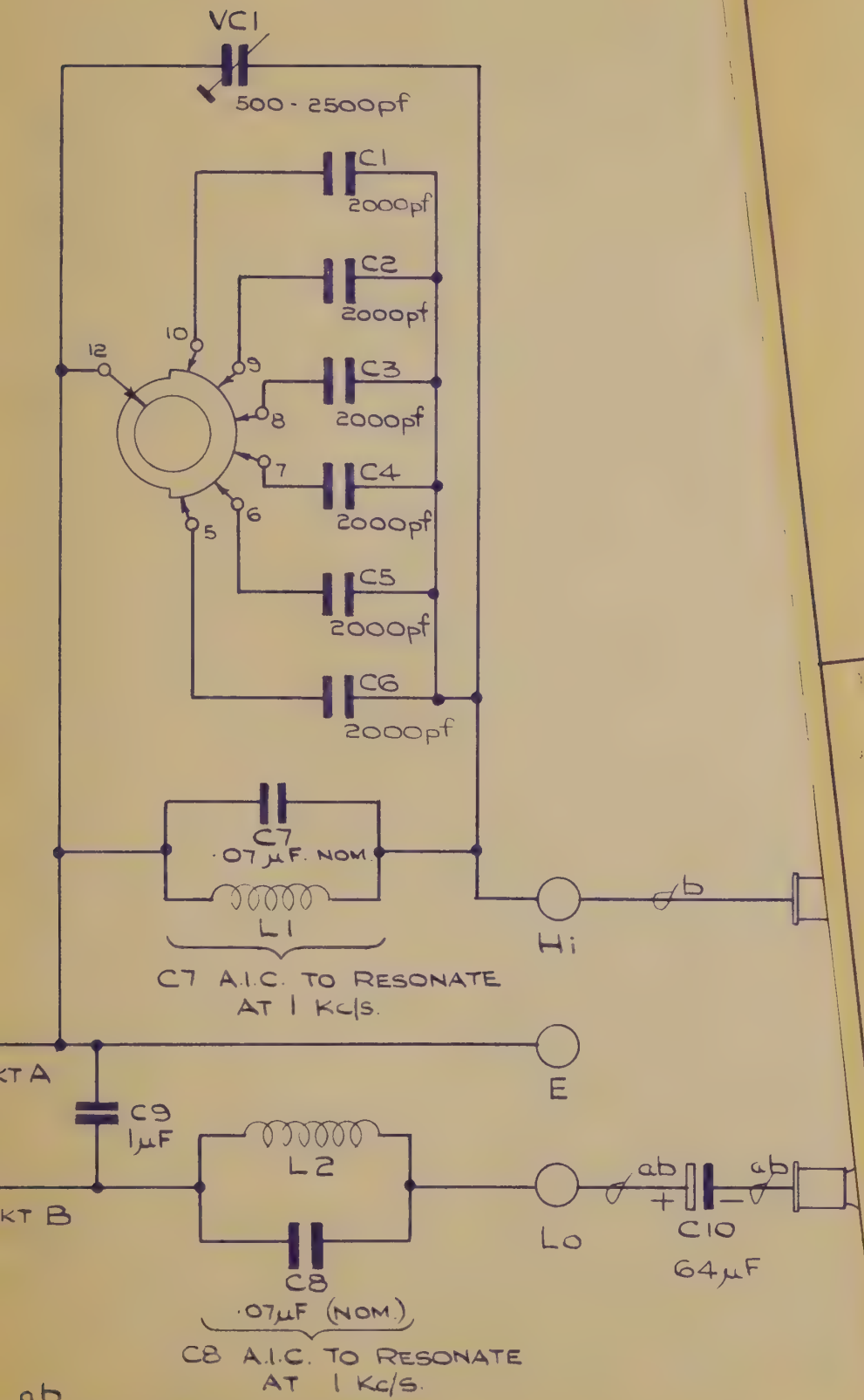
TITLE: CHARTS OF TEST TERMINAL VOLTAGE AT BALANCE							
DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK LIST	DRAWING NUMBER
T.S.	25-7-59			E.M.T.		TF 868B TF 1313	XD 30557
MARCONI INSTRUMENTS LTD.							SHEET OF SHEETS

XD 30557

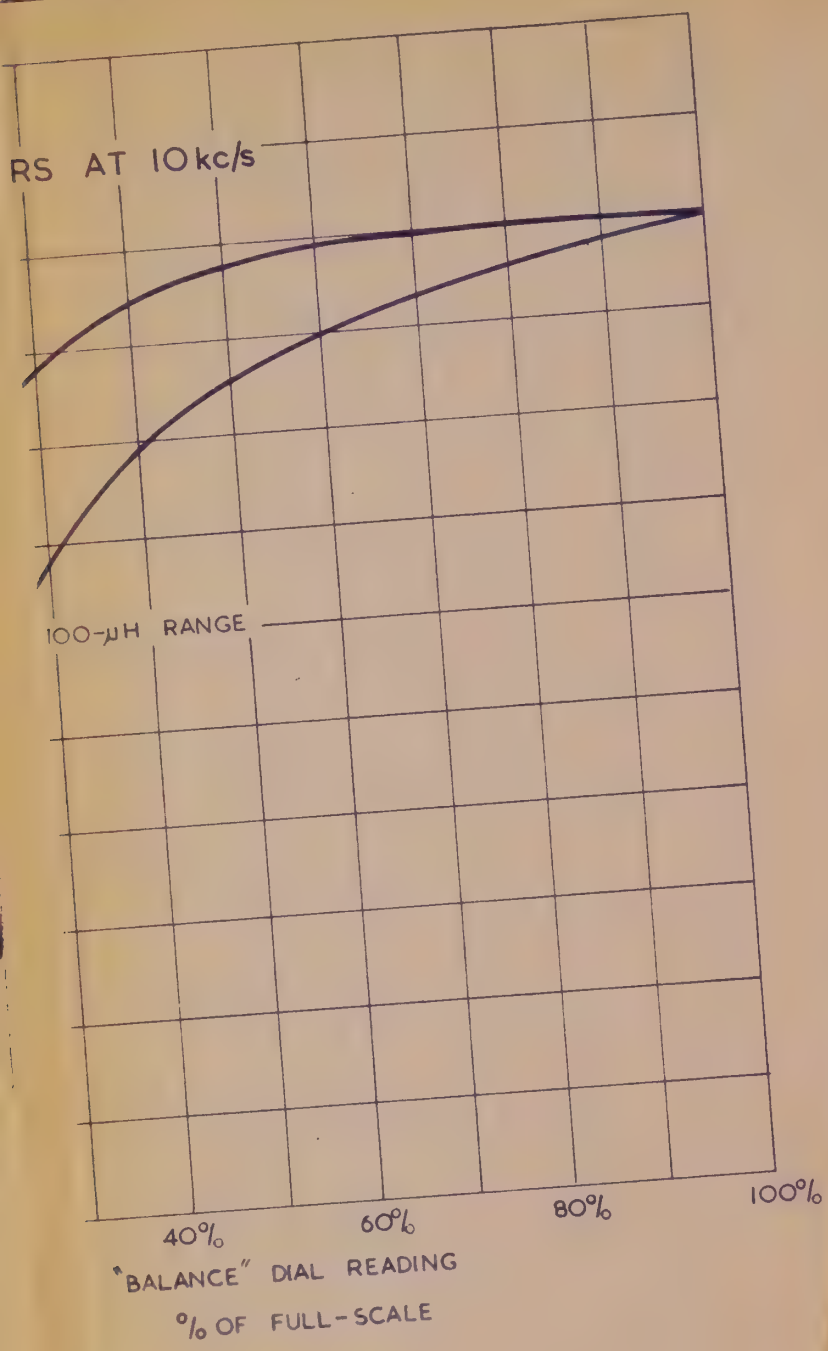


RMINAL VOLTAGE AT BALANCE

XD 3055

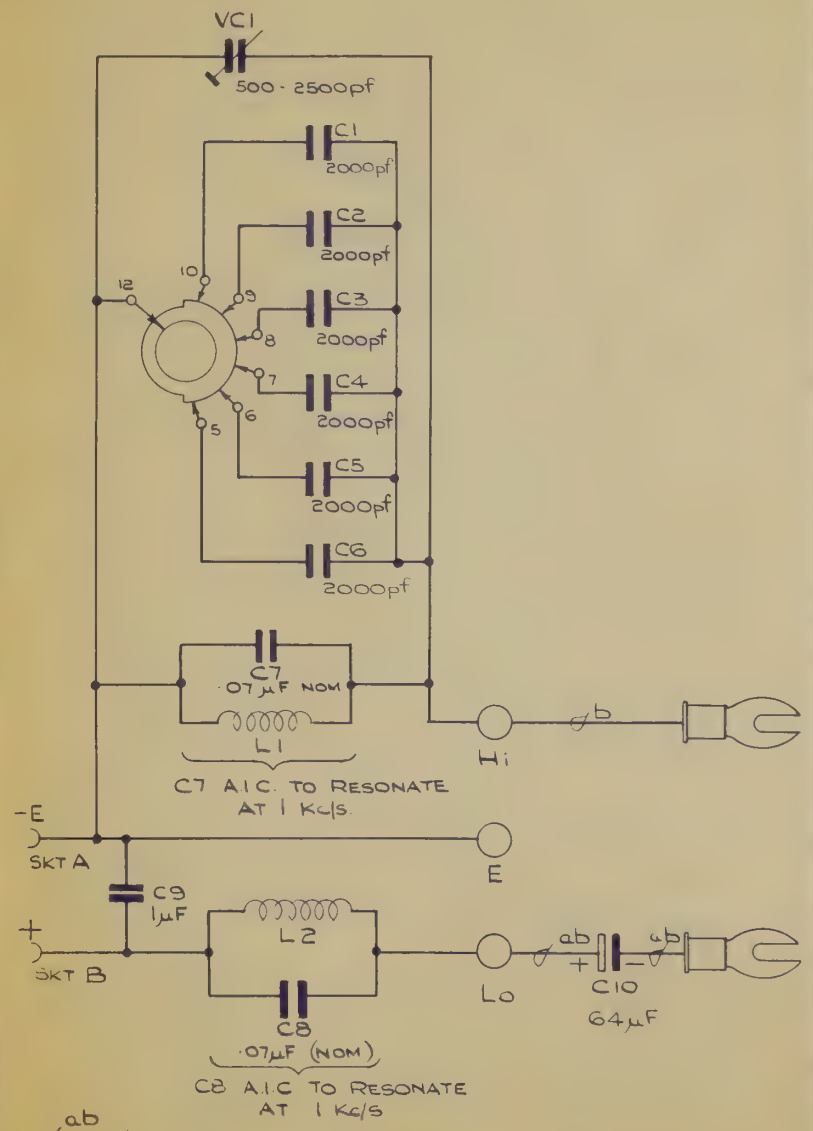

VC1
500 - 2500pf
C1
2000pf
C2
2000pf
C3
2000pf
C4
2000pf
C5
2000pf
C6
2000pf
12
10
9
8
7
6
5
C7
·07 μF. NOM
L1
C7 A.I.C. TO RESONATE
AT 1 Kc/s.
Hi
b
E
KT A
C9
1μF
L2
KT B
C8
·07μF (NOM.)
C8 A.I.C. TO RESONATE
AT 1 Kc/s.
Lo
ab
ab
+
C10
64μF
ab = 1c CABLE TO DEF 10
b = TC 20700/3

XC 31308



RMINAL VOLTAGE AT BALANCE

XD 3055



TITLE: DIRECT CURRENT CHOKE ADAPTOR CIRCUIT DIAGRAM.							
DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK LIST	DRAWING Nº
J PORTER	22-10-59		DW	T.D.S.	TD 31304	TM 6113	XC 31308
MARCONI INSTRUMENTS LTD.							SHEET OF SHEETS

A | B | C

TITLE

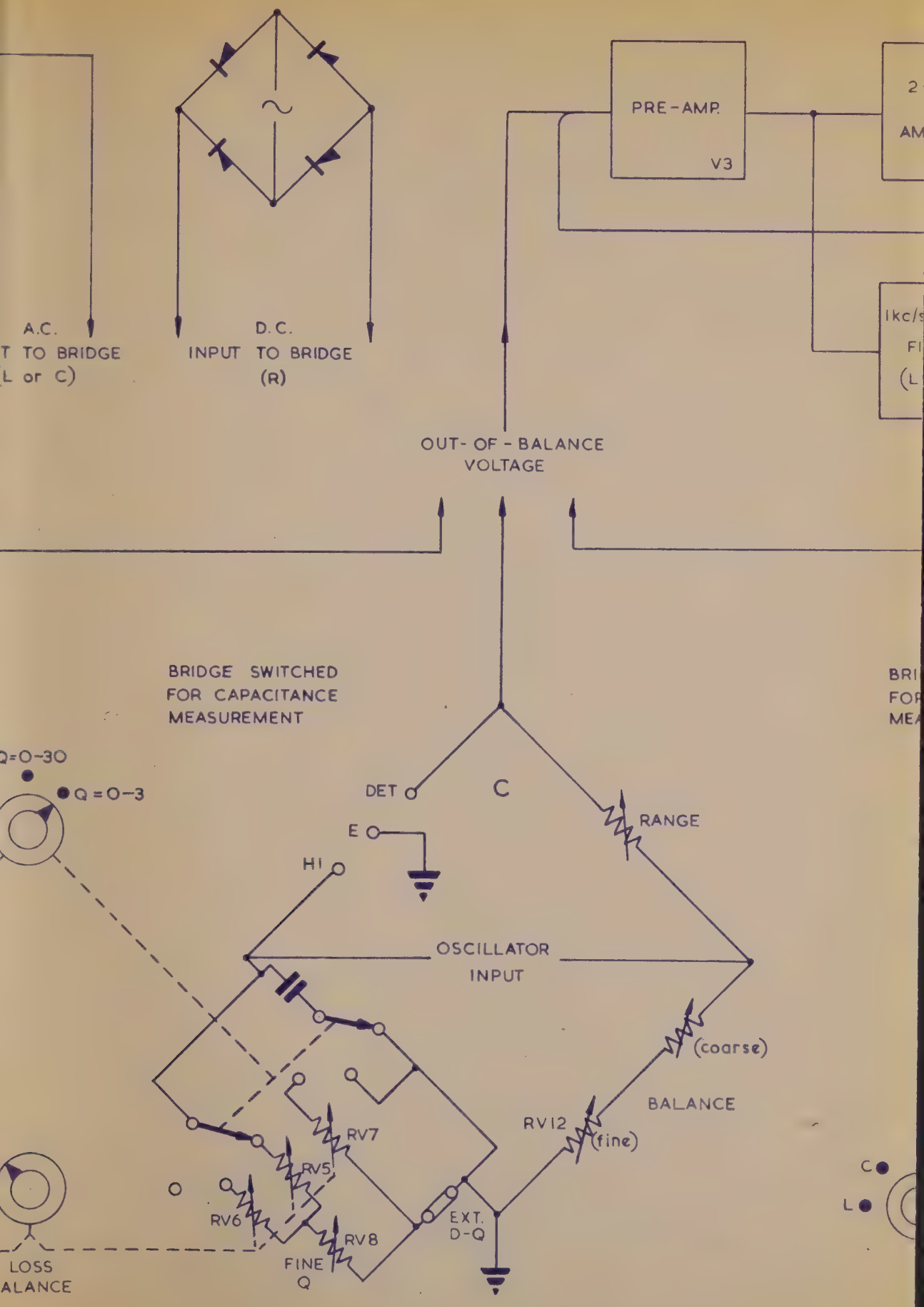
DIRECT CURRENT CHOKE ADAPTOR CIRCUIT DIAGRAM.

DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK LIST	DRAWING Nº
J. PORTER	22-10-59	JT	DW	T.D.S.	TD 31304	TM 6113	XC 31308

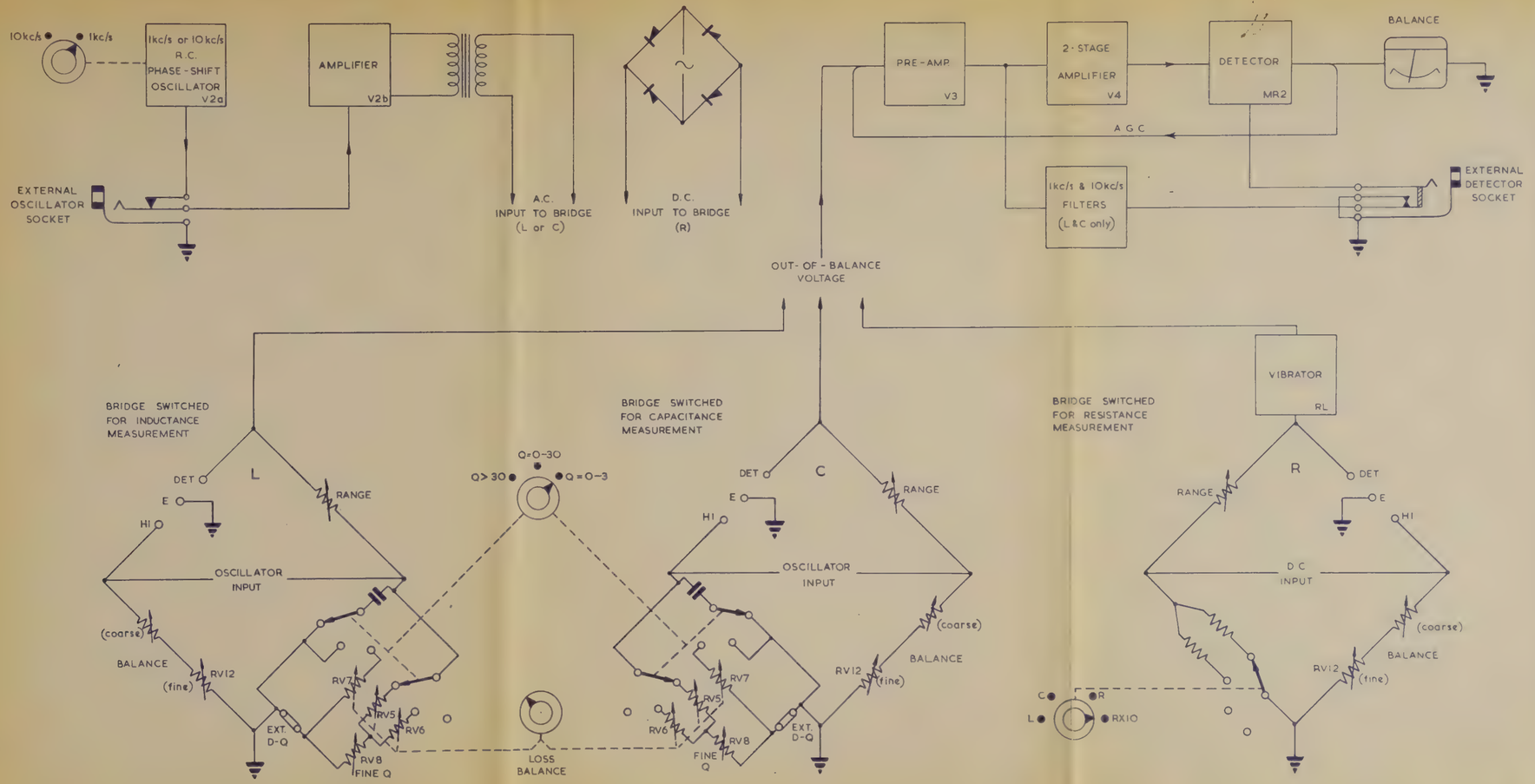
MARCONI INSTRUMENTS LTD.

SHEET OF SHEET

A | B | C



ICTIONAL DIAGRAM OF - UNIVERSAL BRIDGE TYPE TF1313



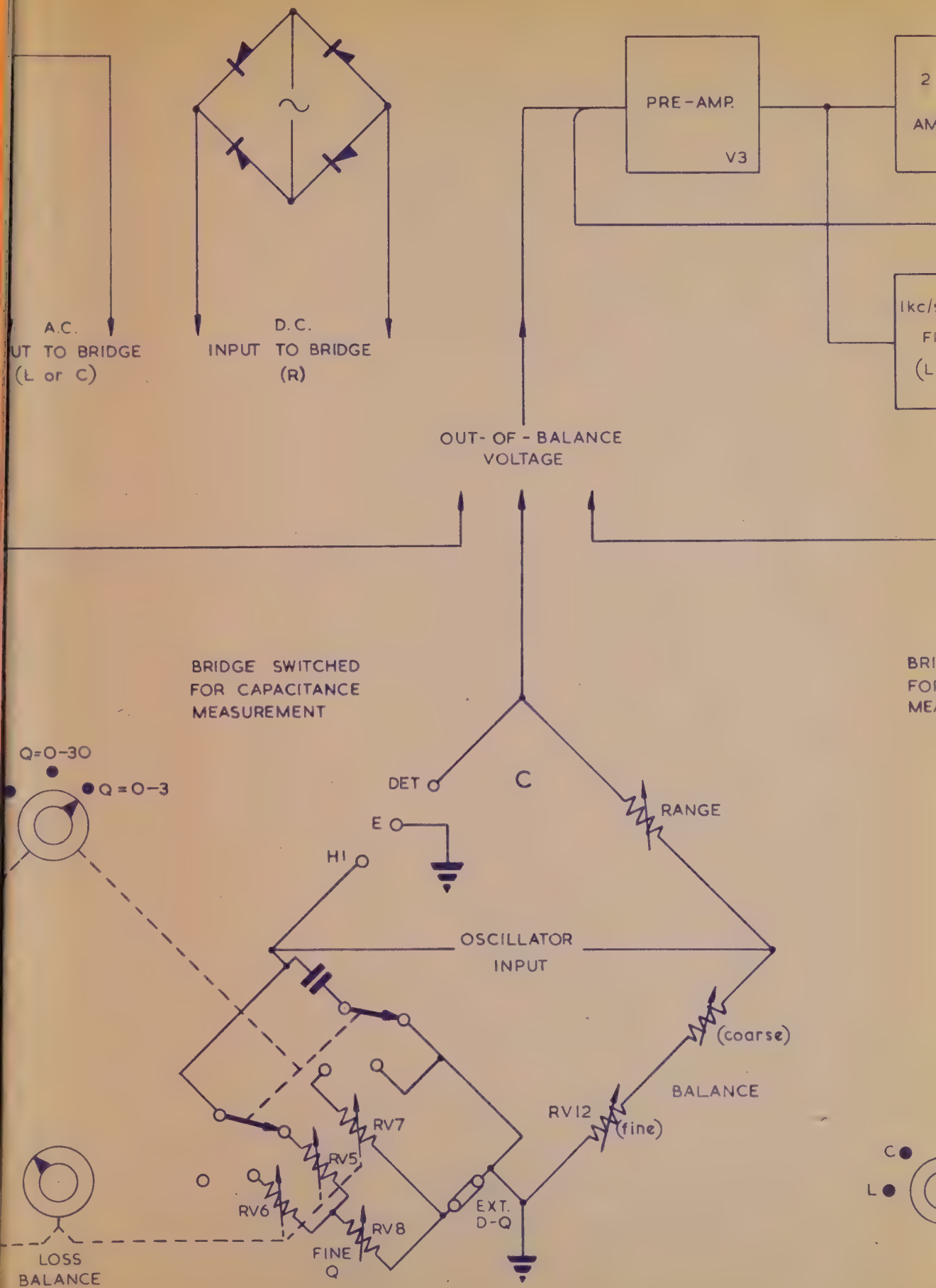
TITLE
FUNCTIONAL DIAGRAM OF UNIVERSAL BRIDGE TYPE TF1313

DRAWN	DATE	CHKD.	APPD.	TR'C.D.	ASSEMBLY	STOCK LIST	DRAWING NUMBER
T.S.	1/61			E.M.T.		TF1313	XD 35166

MARCONI INSTRUMENTS LTD. SHEET 1 OF 1 SHEETS

FUNCTIONAL DIAGRAM OF - UNIVERSAL BRIDGE TYPE TF1313

XD 35166



UNCTIONAL DIAGRAM OF - UNIVERSAL BRIDGE TYPE TF1313

A B C

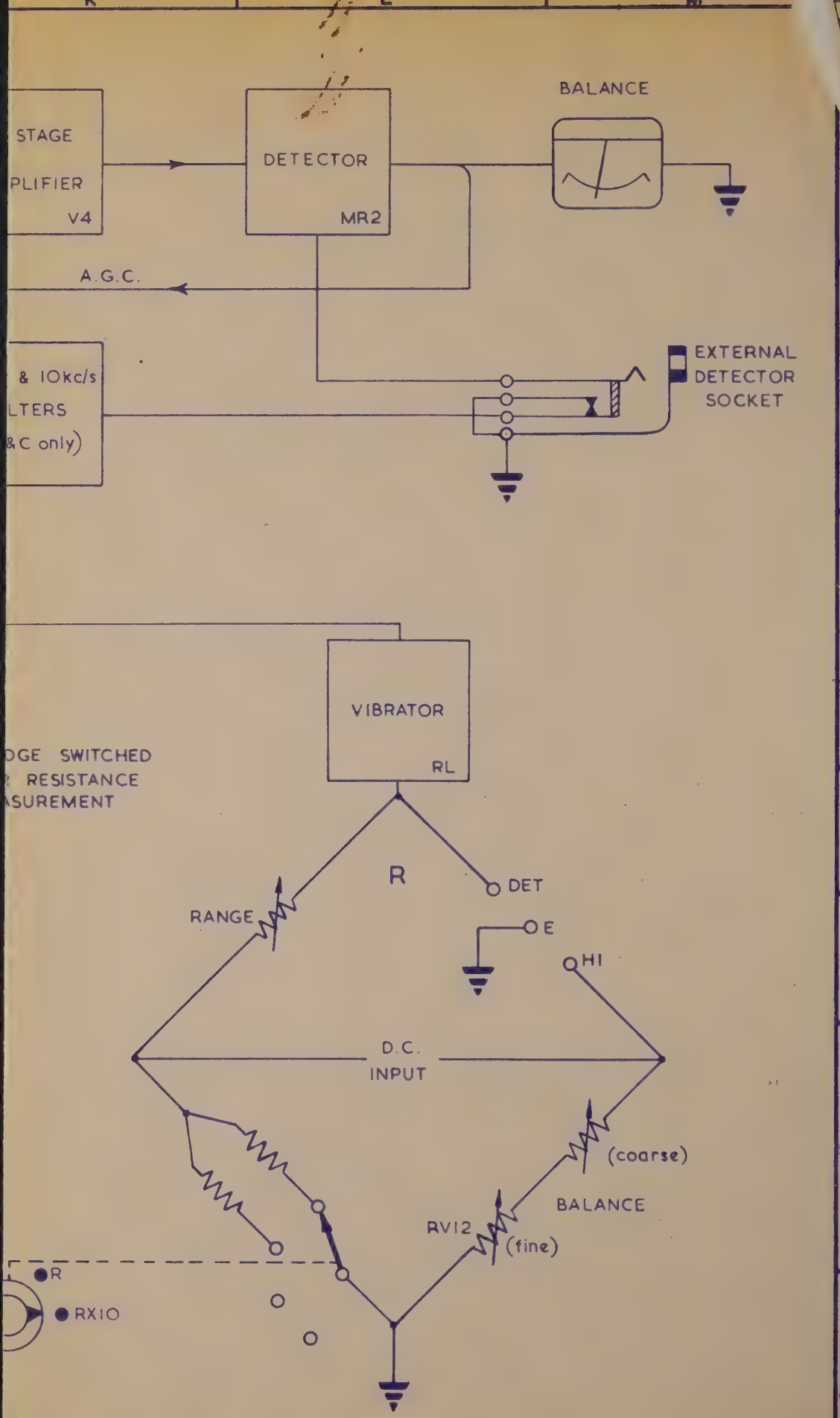
TITLE

DIRECT CURRENT CHOKE ADAPTOR CIRCUIT DIAGRAM.

DRAWN	DATE	CHK'D	APP'D	TRC'D	ASSEMBLY	STOCK LIST	DRAWING Nº
J PORTER	22-10-59		DW	T.D.S.	TD 31304	TM 6113	XC 3130E

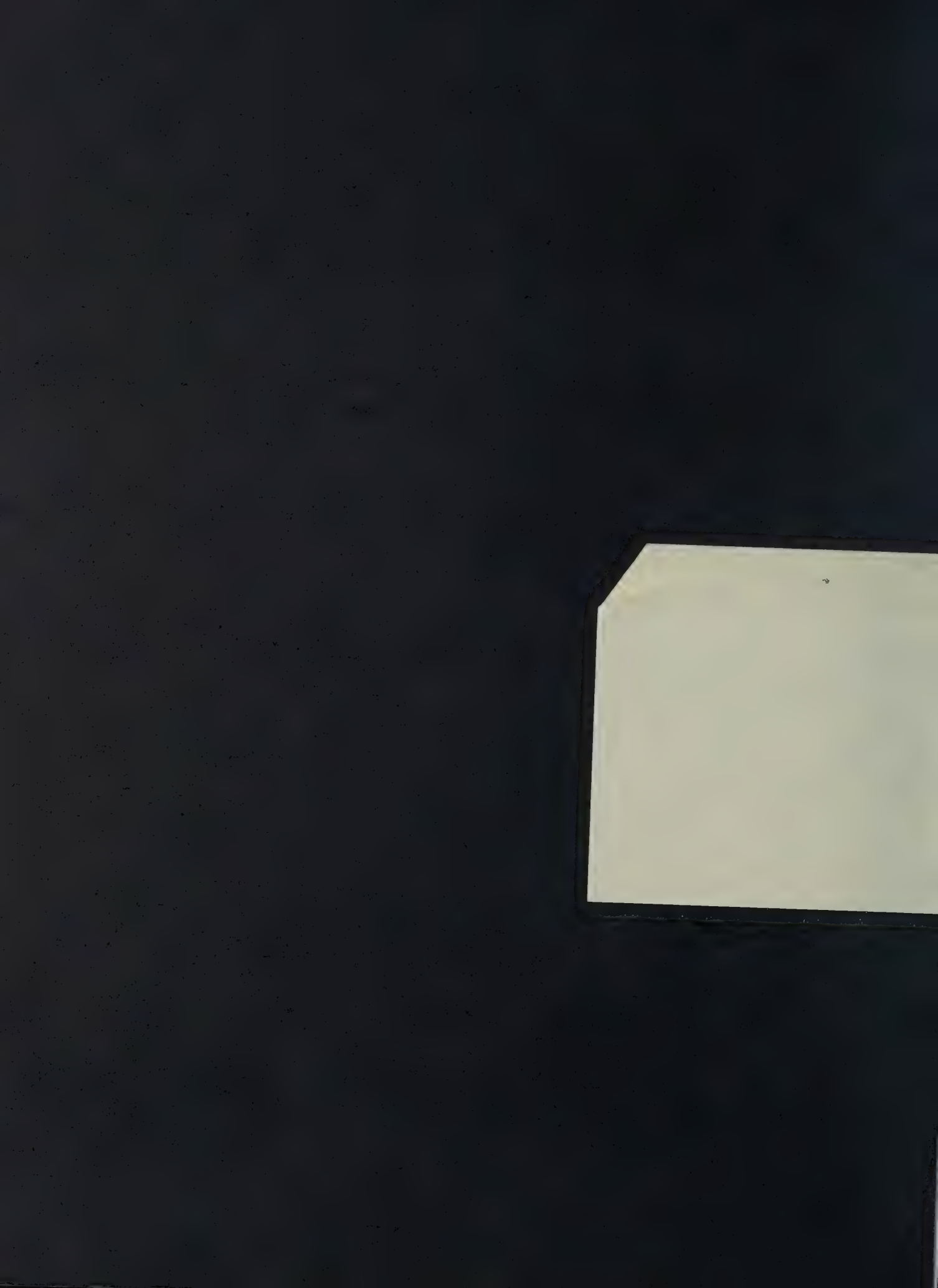
MARCONI INSTRUMENTS LTD. SHEET OF SHEE

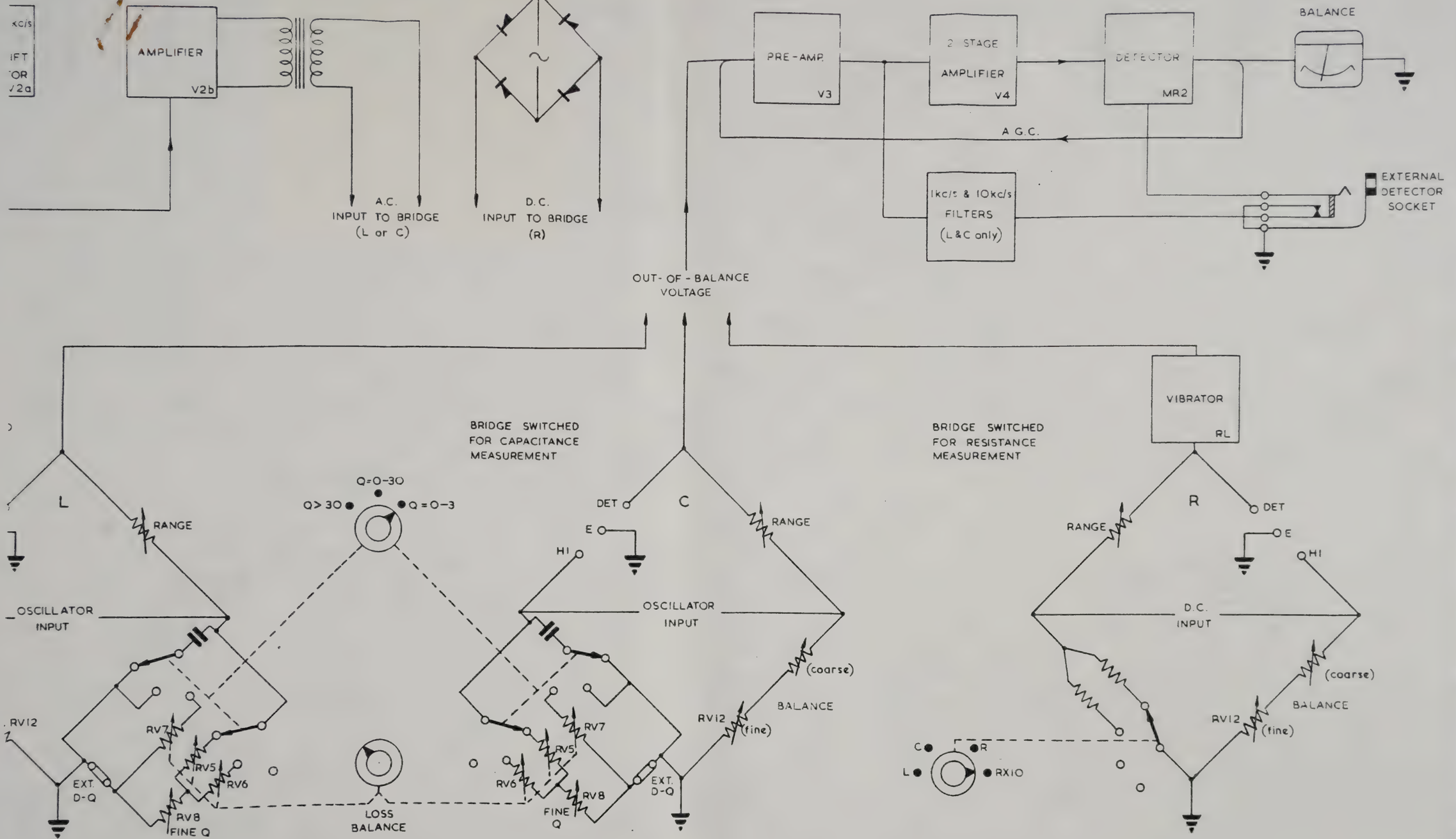
A B C


STAGE
PLIFIER
V4
DETECTOR
MR2
BALANCE
A.G.C.
& 10kc/s
LTERS
&C only)
EXTERNAL
DETECTOR
SOCKET
VIBRATOR
RL
OGE SWITCHED
RESISTANCE
ASUREMENT
R
DET
RANGE
E
HI
D.C.
INPUT
(coarse)
BALANCE
RV12
(fine)
R
RX10

XD 35166

2 sets
ea w/ 8½x11's (3ea)
ea: 6-11x17

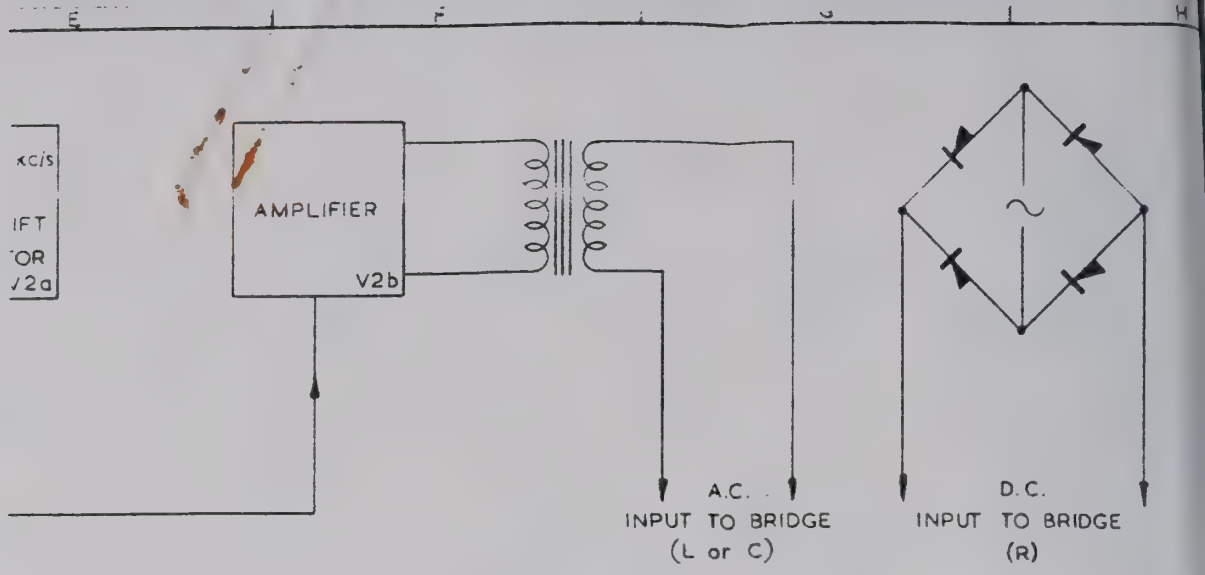


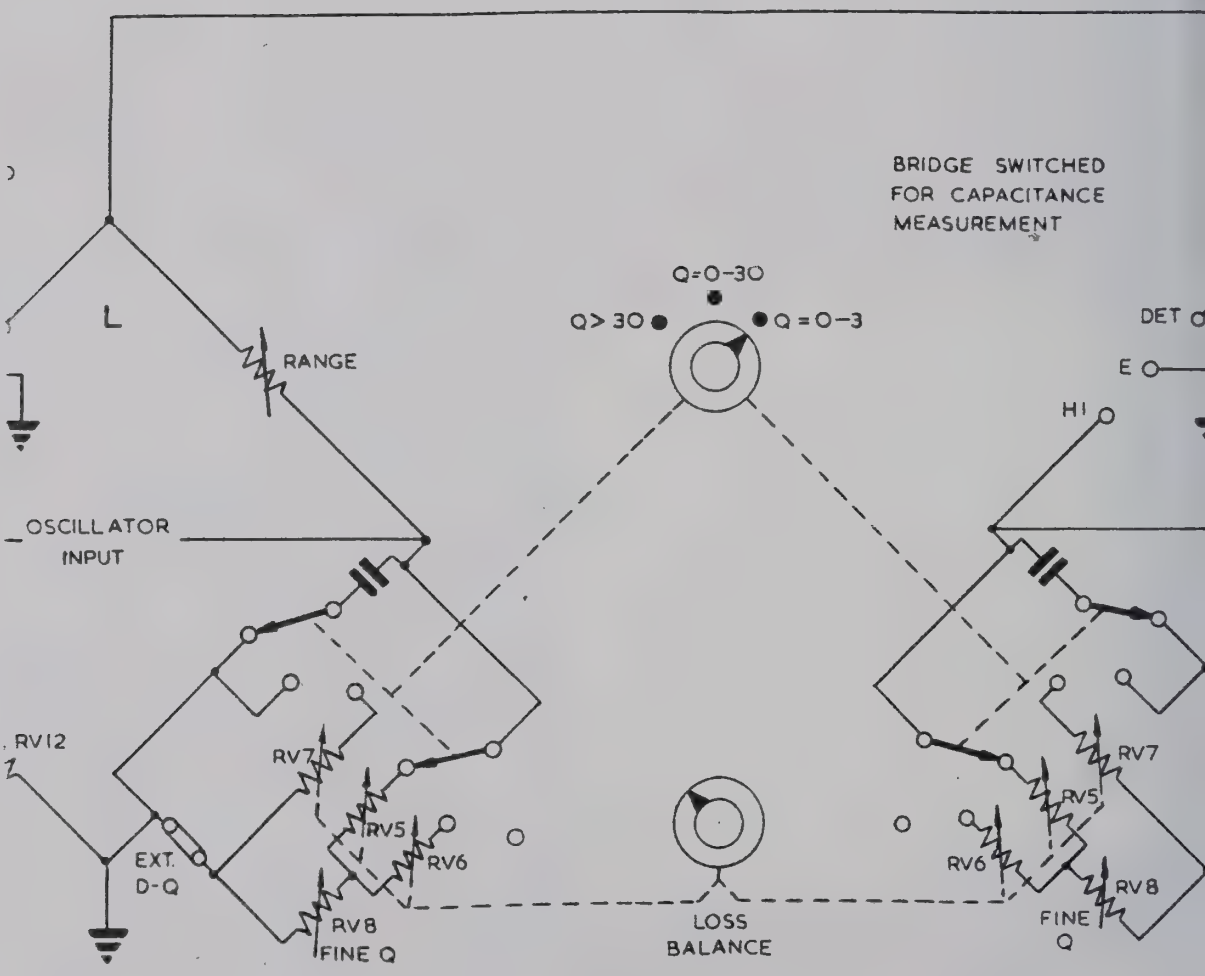


FUNCTIONAL DIAGRAM OF - UNIVERSAL BRIDGE TYPE TF1313

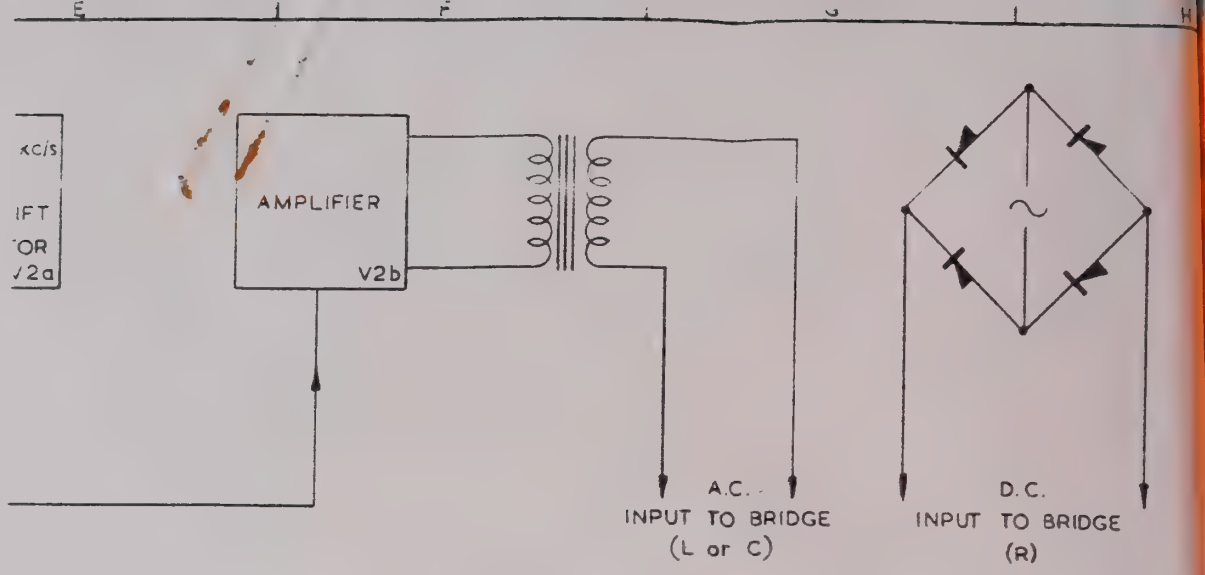
XD 35166

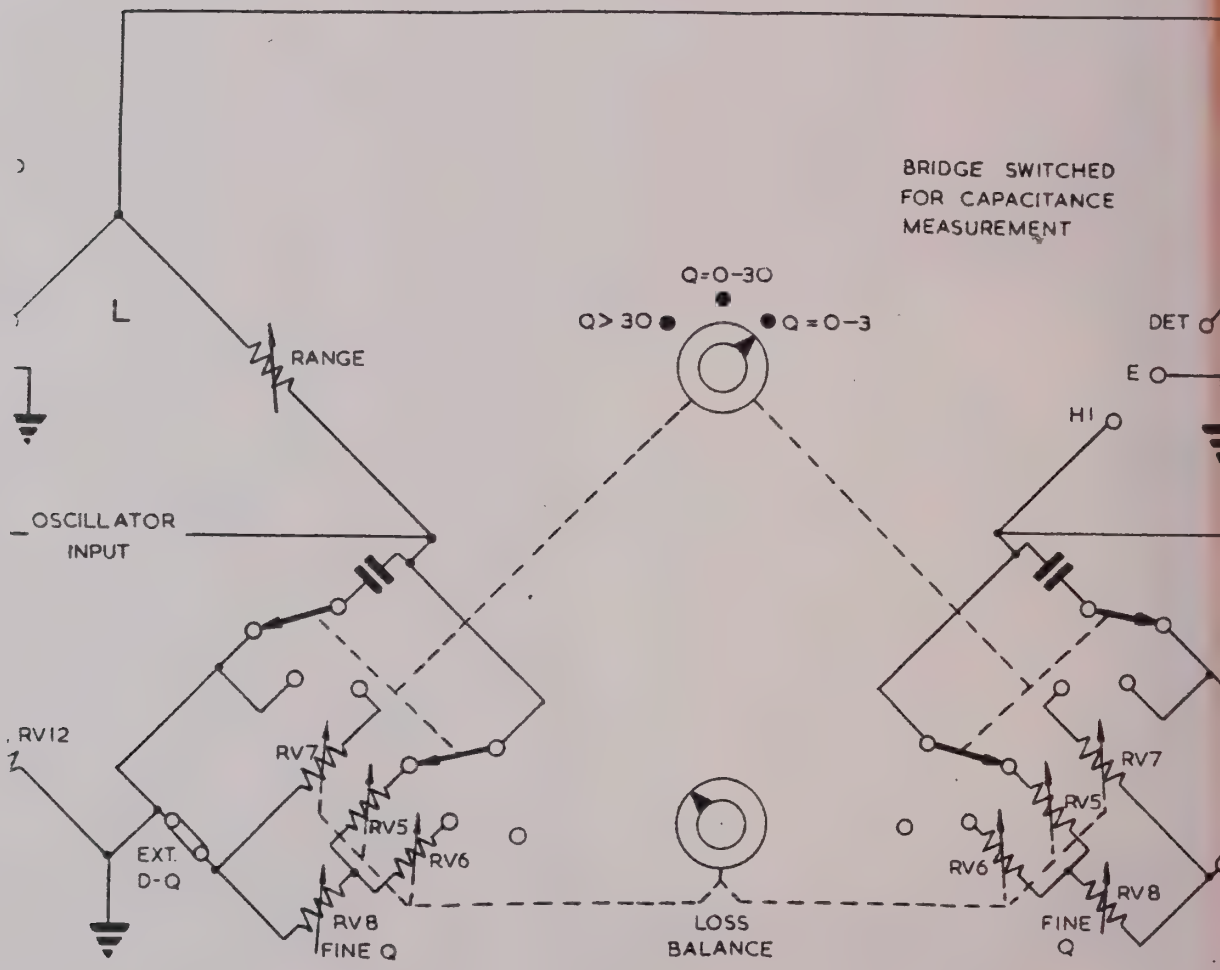
2/2



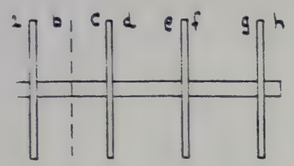


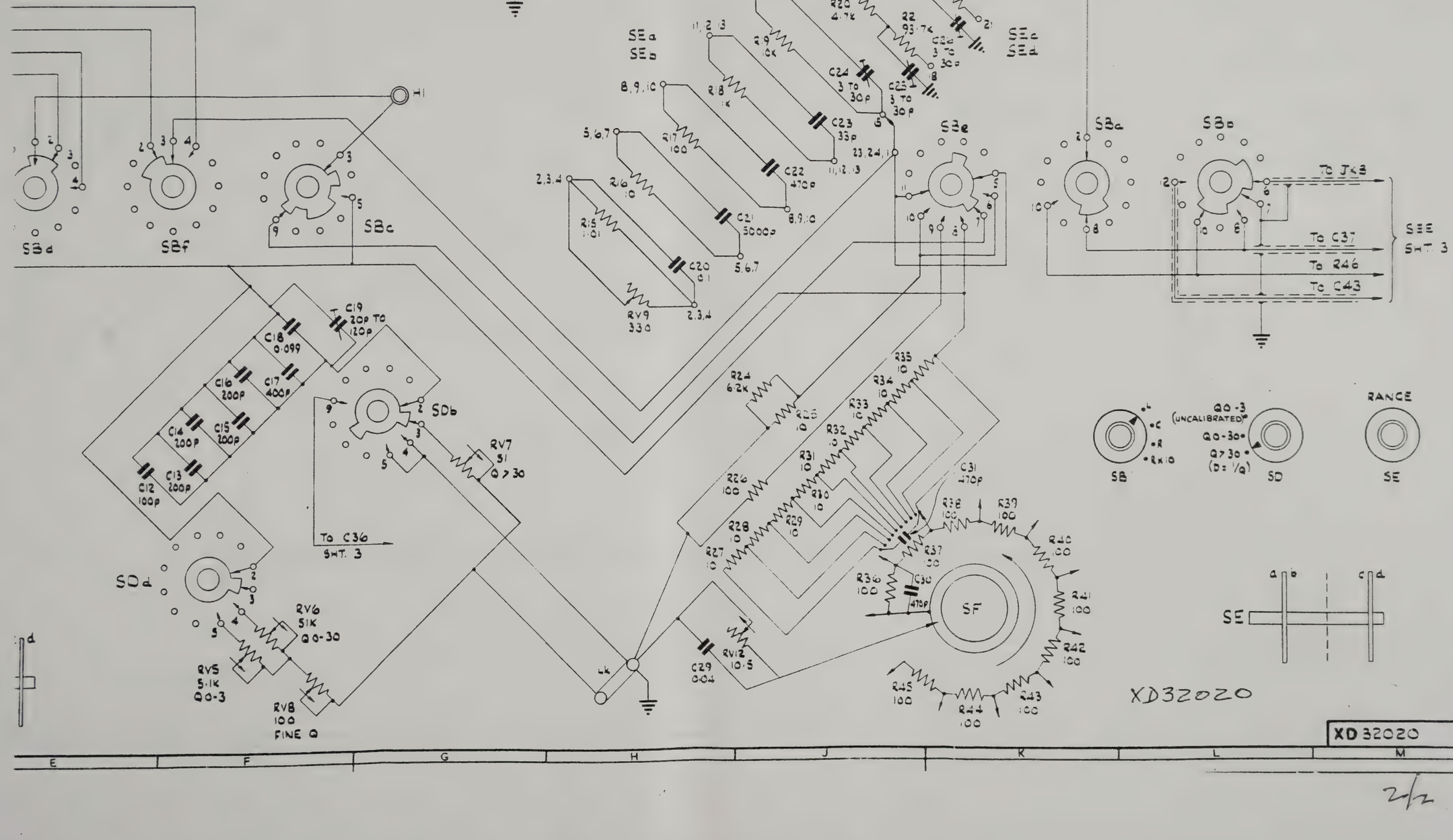
FUNCTIONAL DIAGRAM OF - UNIV

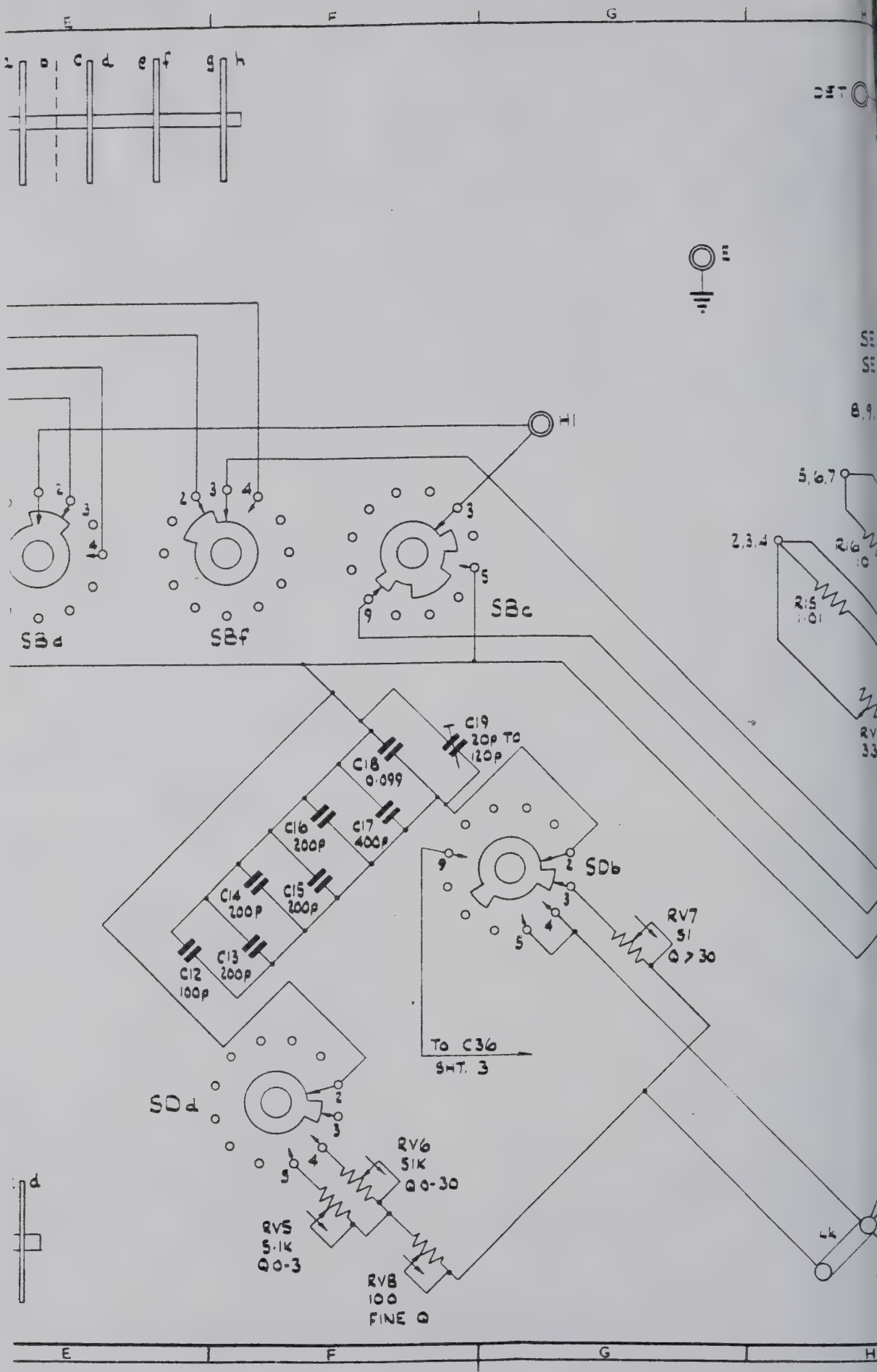


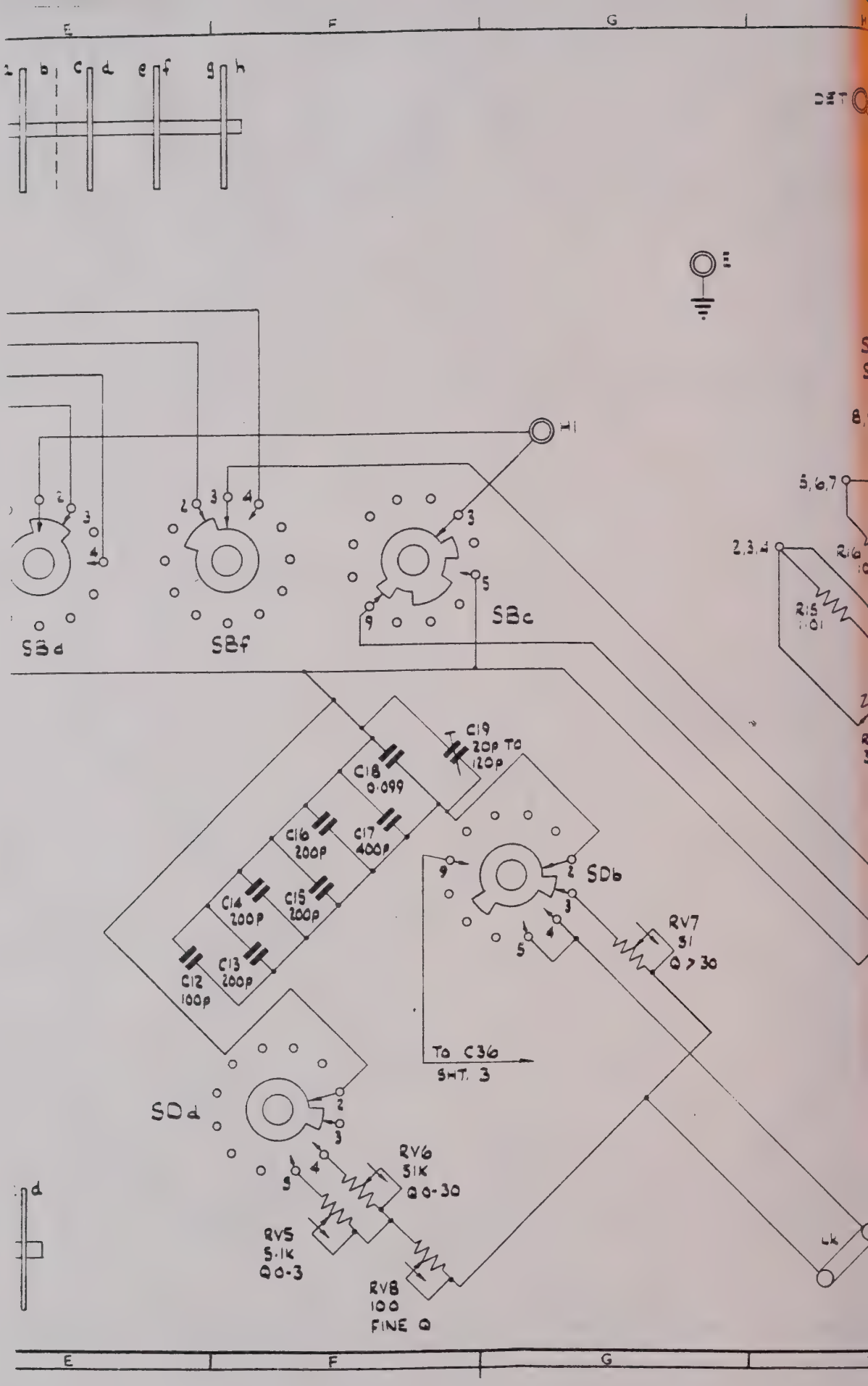


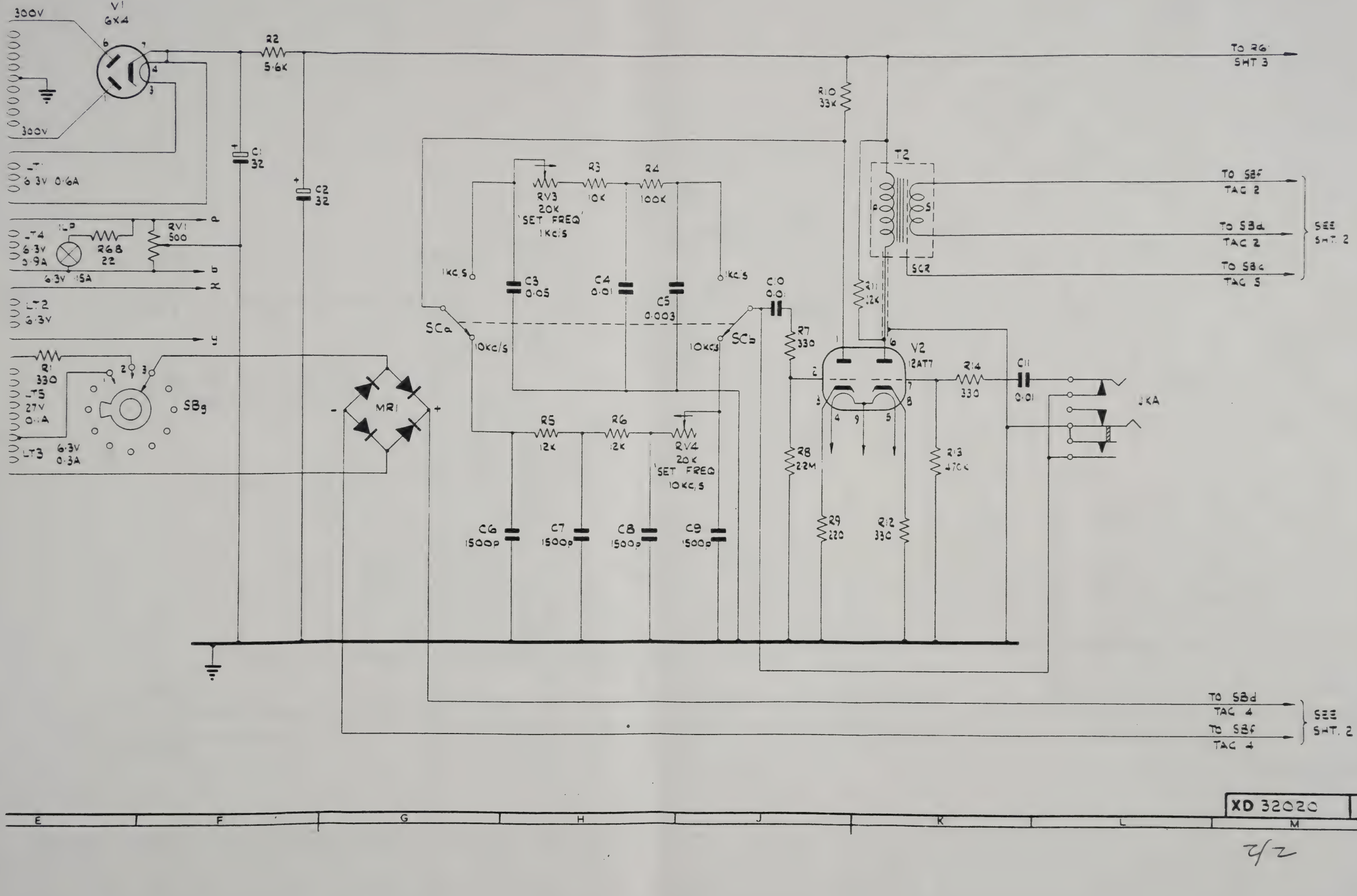
FUNCTIONAL DIAGRAM OF - UNIVE


a
b
c
d
e
f
g
h


DET
E
SEa
SEb
SEc
SEd
SBa
SBb
SBc
SBd
SBe
SBf
SDa
SDb
SDd
SF
H1
K
C28 47p
RV11 33k
R22 47k
C27 470p
RV10 3.3k
R23 937k
R20 4.7k
R22 937k
C26 3 TO 30p
C24 3 TO 30p
C25 3 TO 30p
R19 10k
R18 1k
C23 33p
R17 100
C22 470p
R16 10
C21 3000p
R15 101
C20 0.1
RV9 330
C19 20p TO 120p
C18 0.099
C16 200p
C17 400p
C14 200p
C15 200p
C12 100p
C13 200p
RV7 31 Q>30
RV6 51K Q0-30
RV5 5.1K Q0-3
RV8 100 FINE Q
To C36 SHT. 3
To J43
To C37
To R46
To C43
SEE SHT 3
R24 6.2k
R25 10
R26 100
R27 10
R28 10
R29 10
R30 10
R31 10
R32 10
R33 10
R34 10
R35 10
C31 470p
R38 100
R39 100
R40 100
R41 100
R42 100
R43 100
R44 100
R45 100
C30 470p
C29 004
RV12 10-5
Q0-3 (UNCALIBRATED)
Q0-30
Q>30 (D=1/Q)
RANGE
SB
SD
SE
XD32020

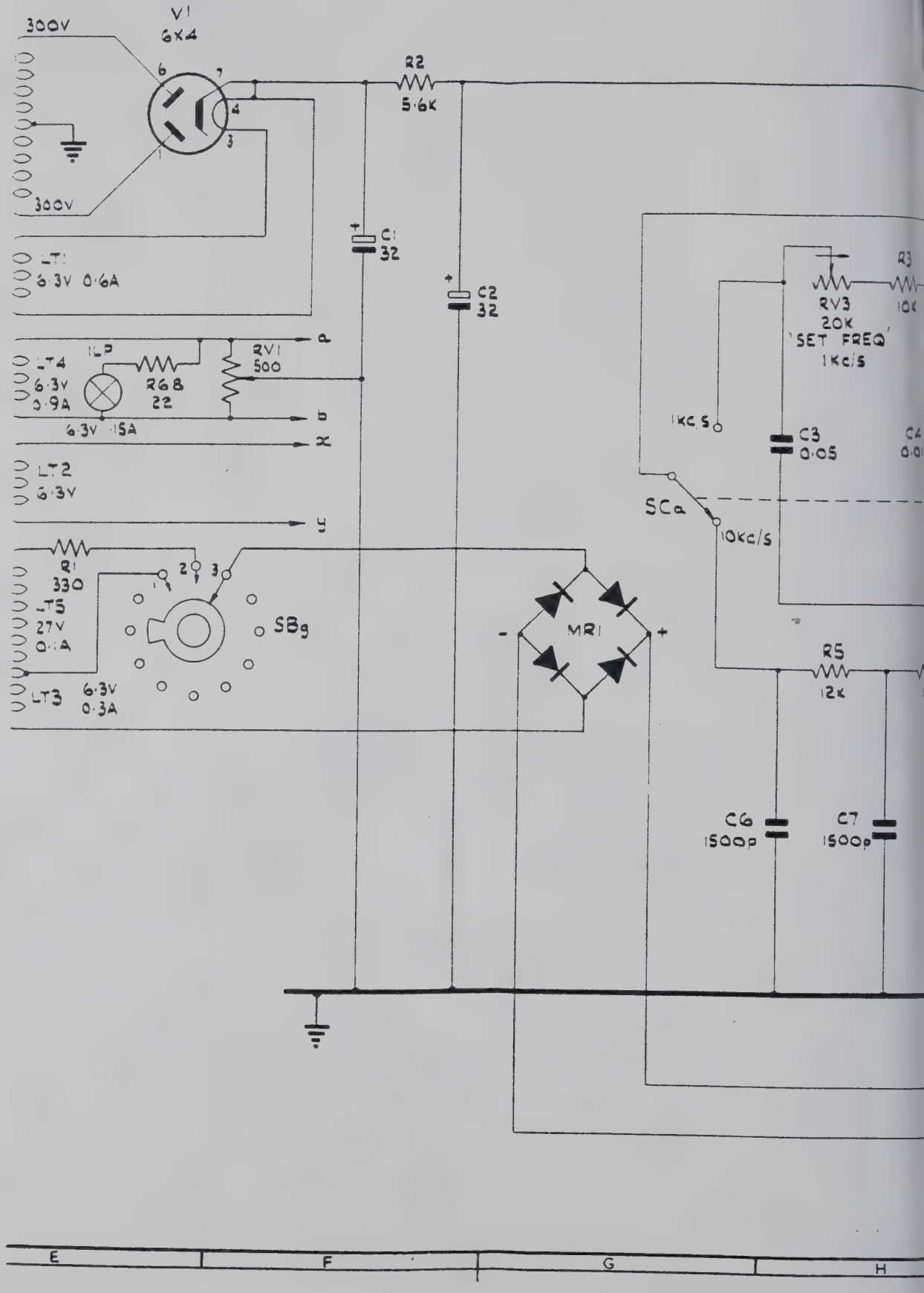

E
F
G
H
a b c d e f g h
DET
E
H1
SBd
SBf
SBc
C19
20p TO
120p
C18
0·099
C16
200p
C17
400p
C14
200p
C15
200p
C13
200p
C12
100p
SDb
RV7
51
Q > 30
To C36
SHT. 3
SDd
RV6
51K
Q 0-30
RV5
5·1K
Q 0-3
RV8
100
FINE Q
5,6,7
2,3,4
R16
R15
1·01
d

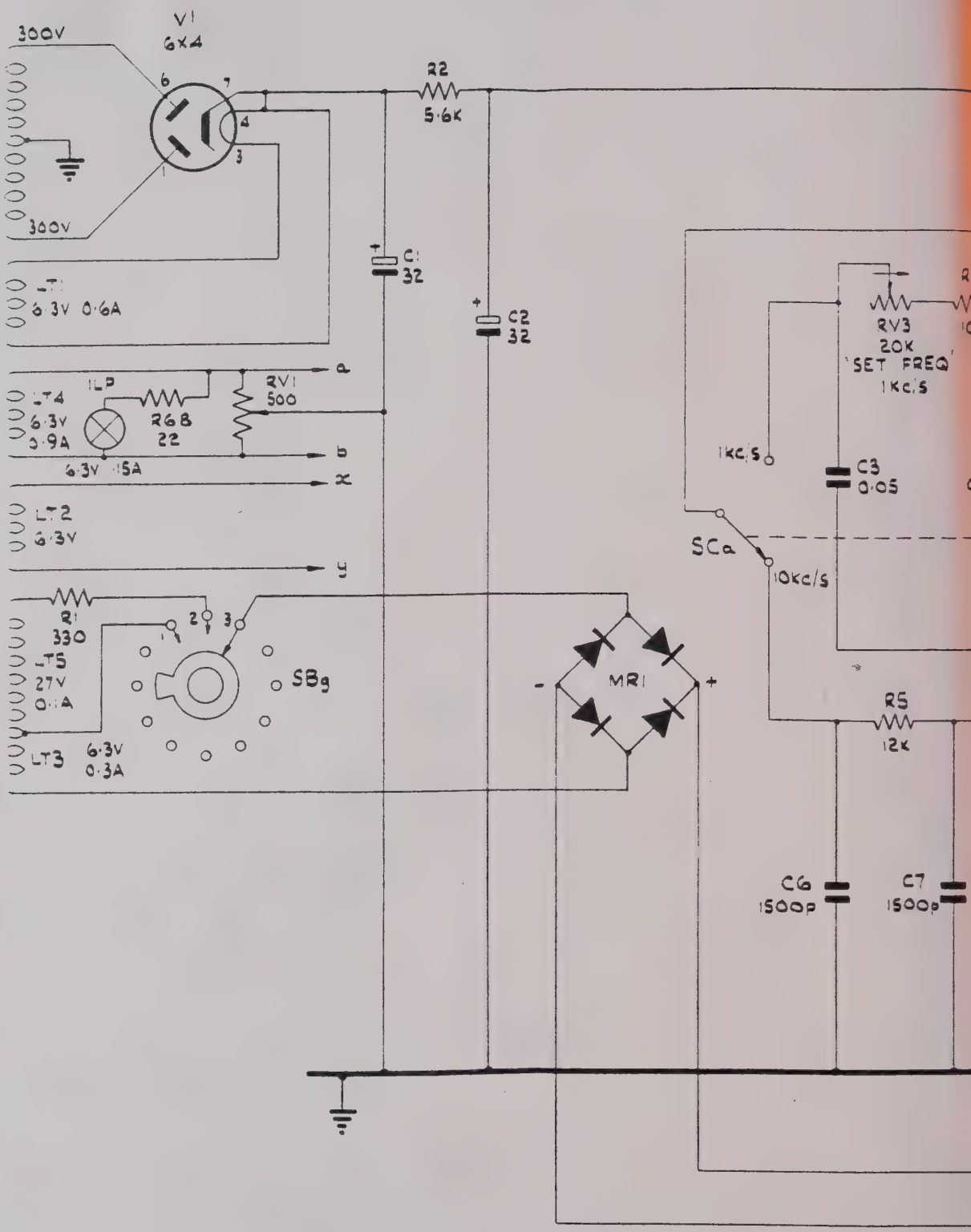

E
F
G
a b c d e f g h
DET
H1
SBd
SBf
SBc
C19 20p TO 120p
C18 0·099
C16 200p
C17 400p
C14 200p
C15 200p
C12 100p
C13 200p
SDb
RV7 31 Ω > 30
To C36 SHT. 3
SDd
RV6 51K Ω 0-30
RV5 5·1K Ω 0-3
RV8 100 FINE Ω
5,6,7
2,3,4
R16
R15
Lk
d


300V
V1
6X4
300V
LT1
6.3V 0.6A
C1
32
C2
32
R2
5.6K
TO R6
SHT 3
R10
33K
T2
P
S1
SCR
TO SBf
TAC 2
TO SBa
TAC 2
TO SBc
TAC 5
SEE
SHT. 2
LT4
6.3V
0.9A
NLP
R68
22
RV1
500
6.3V 1.5A
a
b
x
LT2
6.3V
y
R1
330
LT5
27V
0.1A
SBg
LT3
6.3V
0.3A
MR1
RV3
20K
'SET FREQ'
1Kc/s
R3
10K
R4
100K
1kc/s
1kc/s
C3
0.05
C4
0.01
C5
0.003
C10
0.01
SCa
SCb
10kc/s
10kc/s
R7
330
V2
12AT7
R14
330
C11
0.01
JKA
R11
1.2K
R5
12K
R6
12K
RV4
20K
'SET FREQ'
10KC/S
R8
2.2M
R13
470K
R9
220
R12
330
C6
1500p
C7
1500p
C8
1500p
C9
1500p
TO SBd
TAC 4
TO SBf
TAC 4
SEE
SHT. 2

XD 32020

2/2


300V
V1
6X4
6
7
4
3
1
300V
R2
5·6K
C1
32
C2
32
LT1
6·3V 0·6A
LT4
6·3V
0·9A
ILP
R68
22
6·3V ·15A
RV1
500
a
b
x
LT2
6·3V
y
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
1
2
3
SBg
MR1
-
+
RV3
20K
'SET FREQ'
1Kc/s
R3
10K
1Kc/s
C3
0·05
C4
0·01
SCa
10Kc/s
R5
12K
C6
1500p
C7
1500p


300V
V1
6X4
6
7
4
3
1
300V
R2
5·6K
C1
32
C2
32
LT1
6·3V 0·6A
ILP
LT4
6·3V
0·9A
R68
22
6·3V ·15A
RV1
500
a
b
x
LT2
6·3V
y
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
SBg
MR1
RV3
20K
'SET FREQ'
1Kc/s
1Kc/s
C3
0·05
SCa
10Kc/s
R5
12K
C6
1500p
C7
1500p

NOTE :- WIRING IN MINIATURE CABLE Nº 1C SHOWN THUS :- ⫽⫽⫽ x

TO H.T. SHT. 1

TO SDb TAC 9

TO SBb TAC 8

TO SBb TAC 10

TO SBb TAC 12

TO SBb TAC 6

C36 0.003

R52 68K

C37 470p

C38 470p

R51 1M

R46 150K

R47 150K

R48 150K

R49 150K

R50 1M

RL

C32 0.1

C34 0.1

C33 0.1

C35 0.1

SBh

RV2 500

SEE SHT. 1

R54 470K

R55 220K

C39 0.01

V3 EF86

R53 10M

R56 330K

R57 2.2K

R58 1M

C40 8

C41 120p S.I.C.

L1

C42 0.01

L2

C44 0.01

C43 0.003

R59 4.7M

R61 33K

R63 4.7K

R62 150K

C45 0.05

C46 0.003

V4 12AX7

SEE SHT. 1

R60 1.5K

R64 100

RV13 1.5K

R65 1M

MR2 OA73

R66 10M

R67 100K

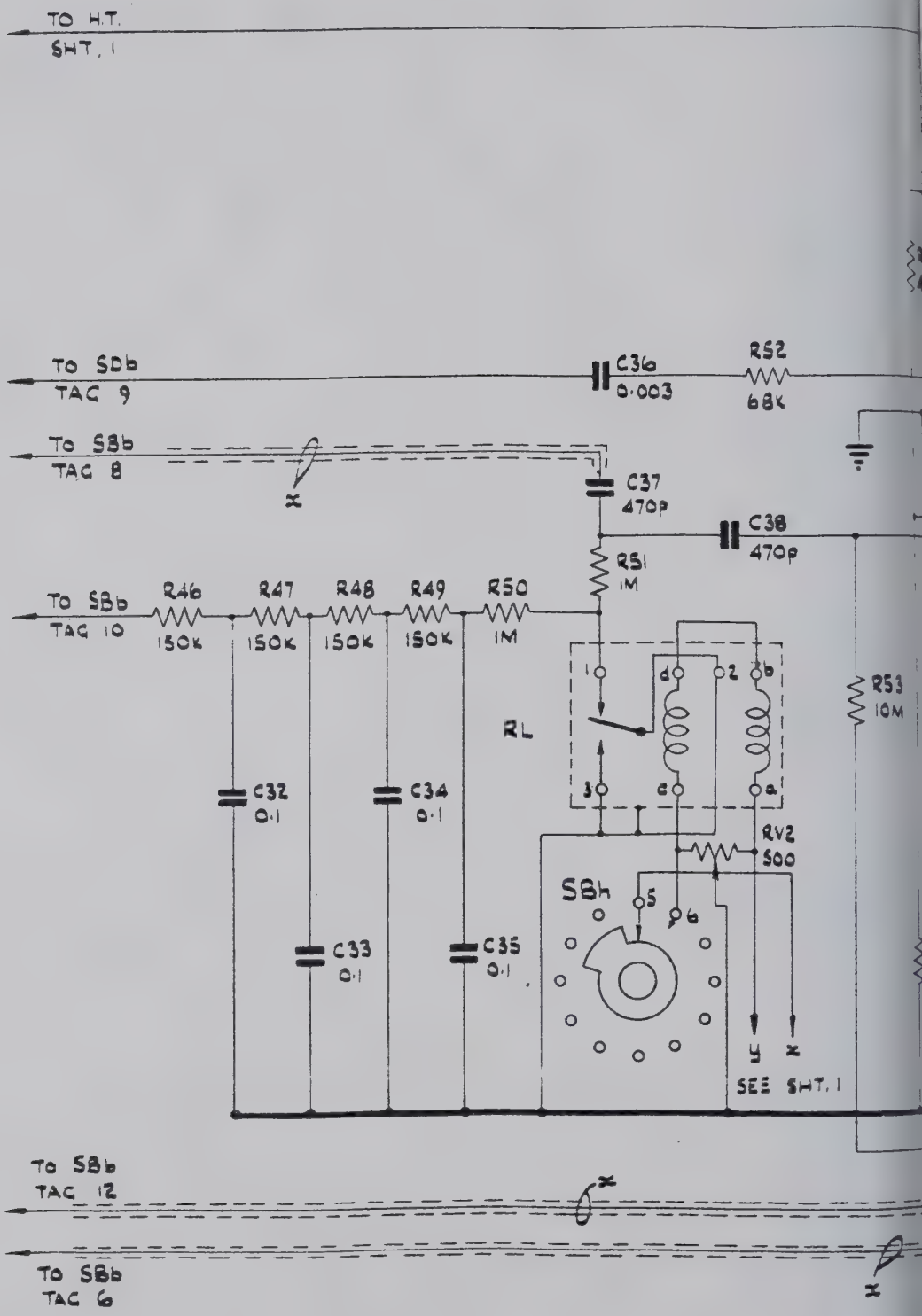
M1 100μA

C47 1

XD 32020

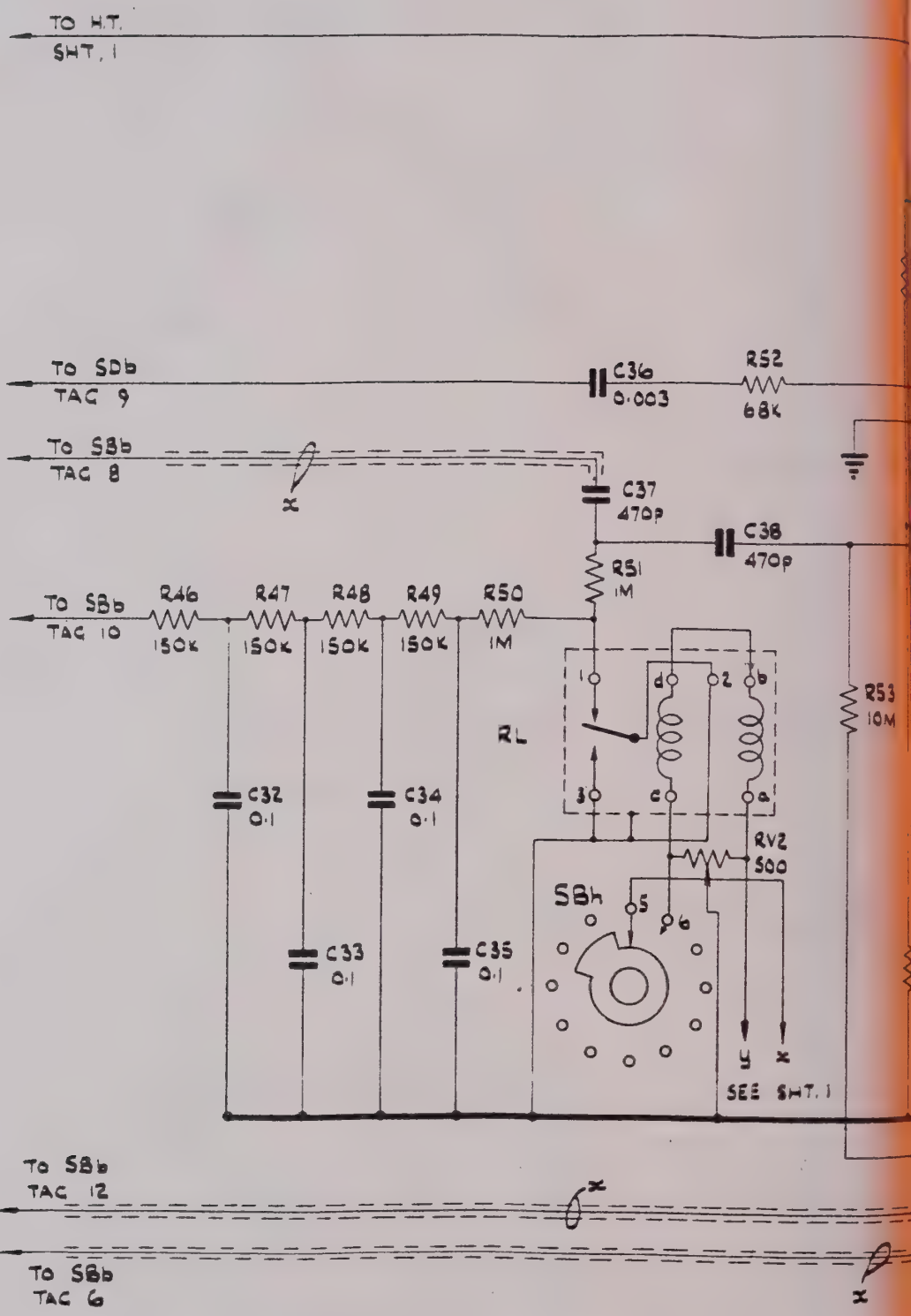
D E F

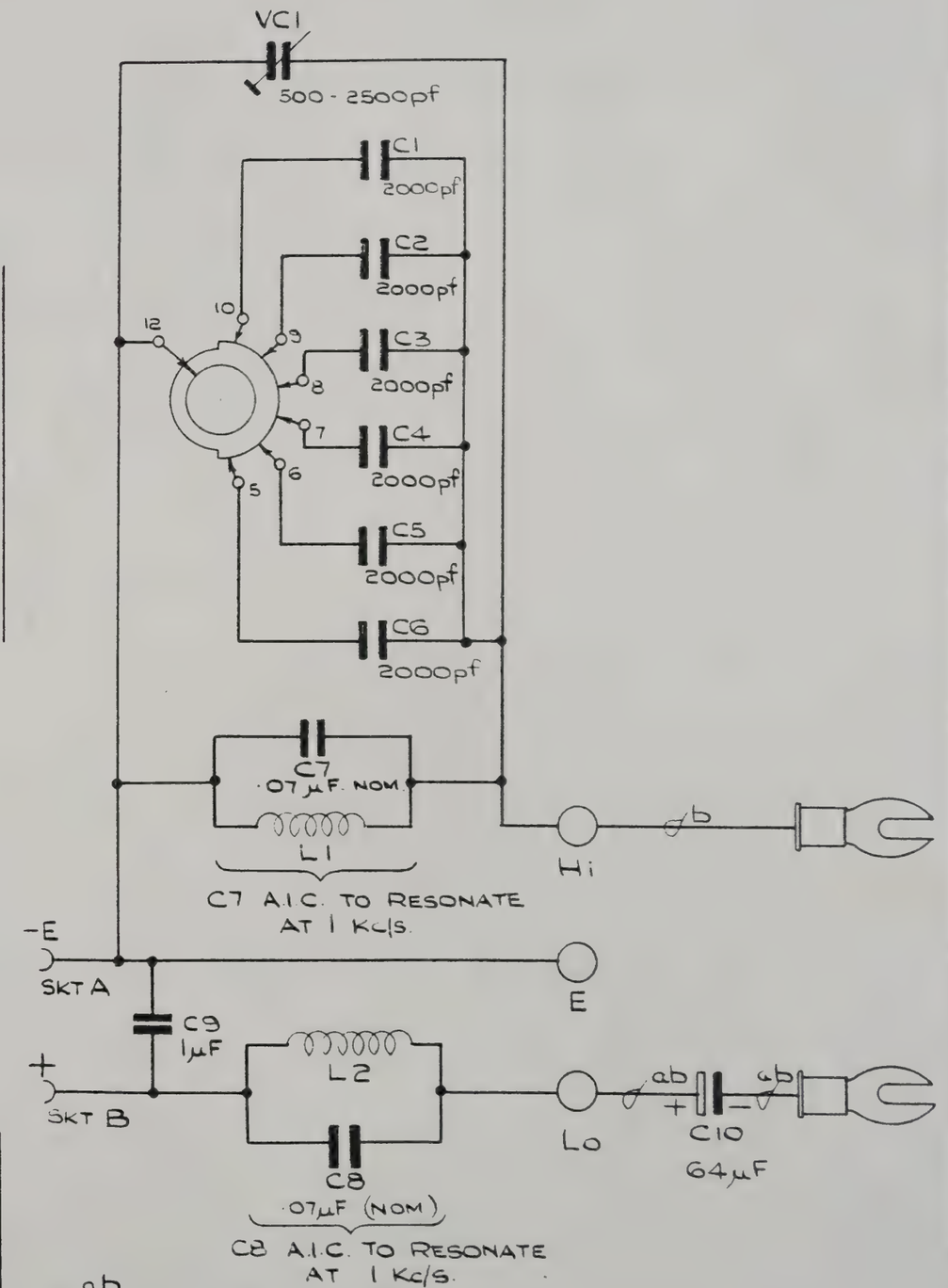
NOTE :- WIRING IN MINIATURE CABLE N° 1C SHOWN THUS :- x



D E F G

NOTE :- WIRING IN MINIATURE CABLE Nº 1C SHOWN THUS :-





TITLE
DIRECT CURRENT CHOKE ADAPTOR CIRCUIT DIAGRAM.

DRAWN	DATE	CHK'D	APP'D	T.R.C.D.	ASSEMBLY	STOCK LIST	DRAWING Nº
J. PORTER	22-10-59		DW	T.D.S.	TD 31304	TM 6113	XC 31308
MARCONI INSTRUMENTS LTD.							SHEET OF SHEETS

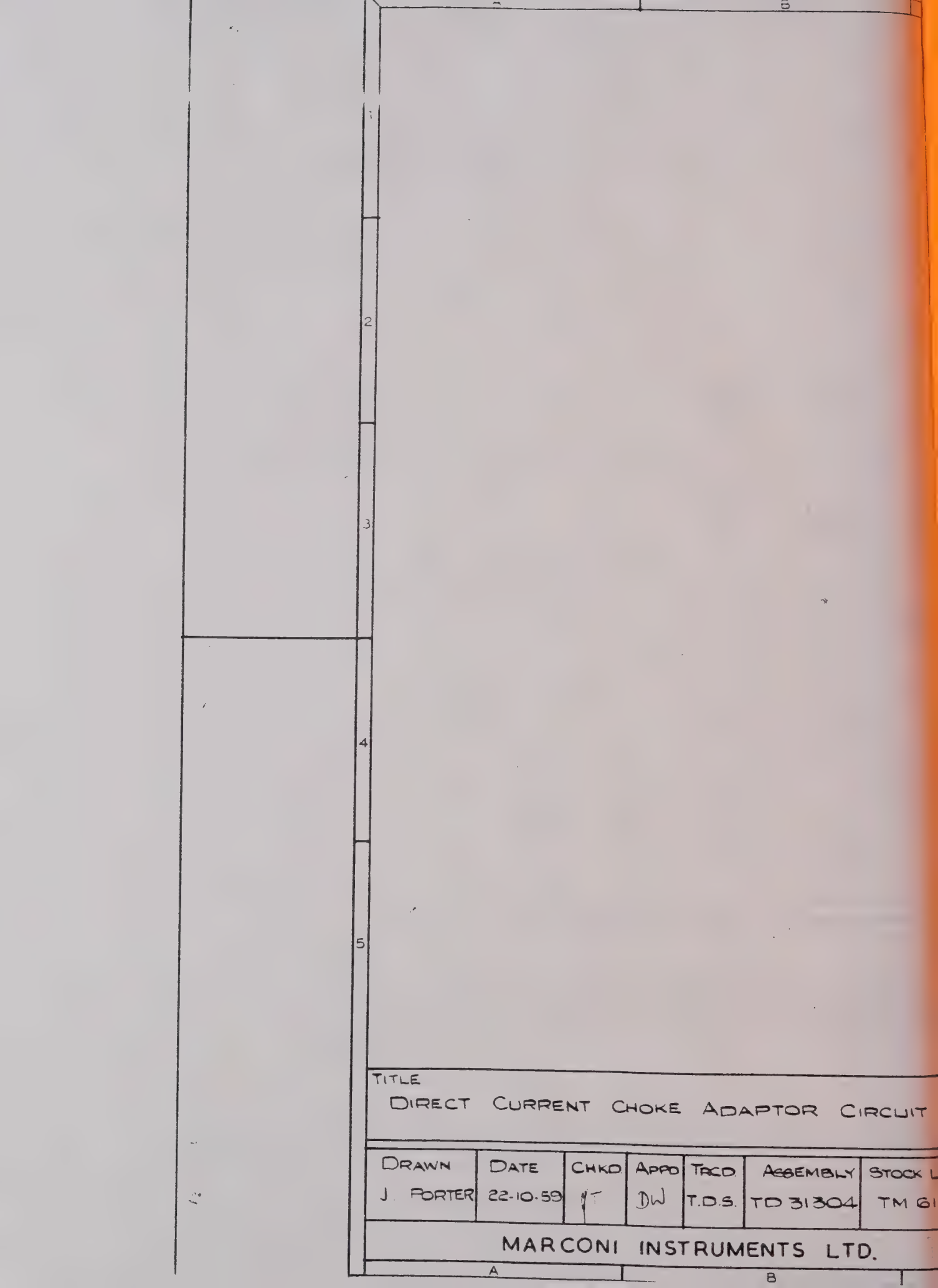
TITLE

DIRECT CURRENT CHOKE ADAPTOR CIRCUIT D

DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK LIS
J. PORTER	22-10-59		DW	T.D.S.	TD 31304	TM 611

MARCONI INSTRUMENTS LTD.

A B

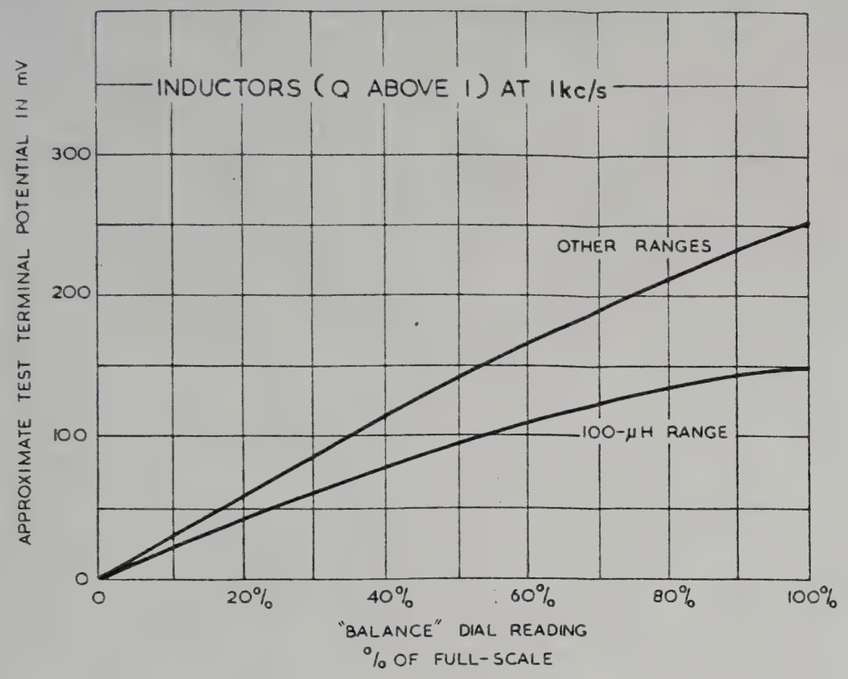


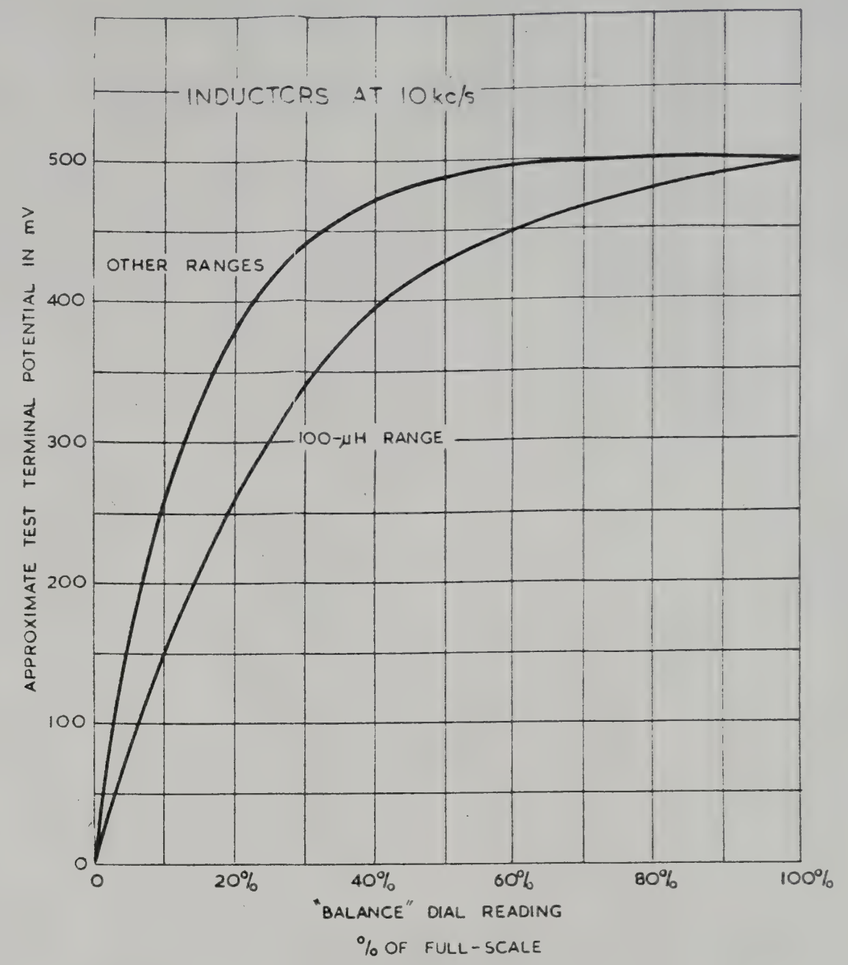
TITLE

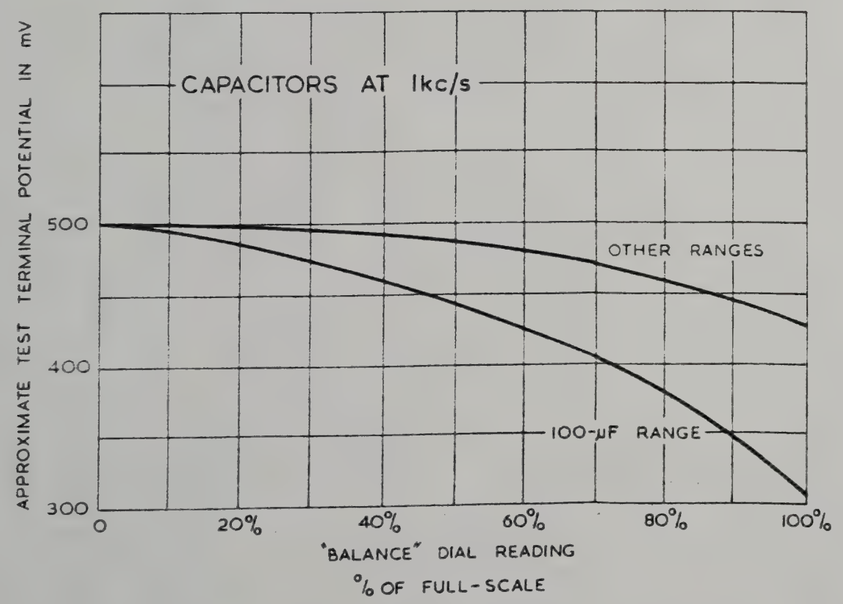
DIRECT CURRENT CHOKE ADAPTOR CIRCUIT

DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK L
J. PORTER	22-10-59		DW	T.D.S.	TD 31304	TM 61

MARCONI INSTRUMENTS LTD.

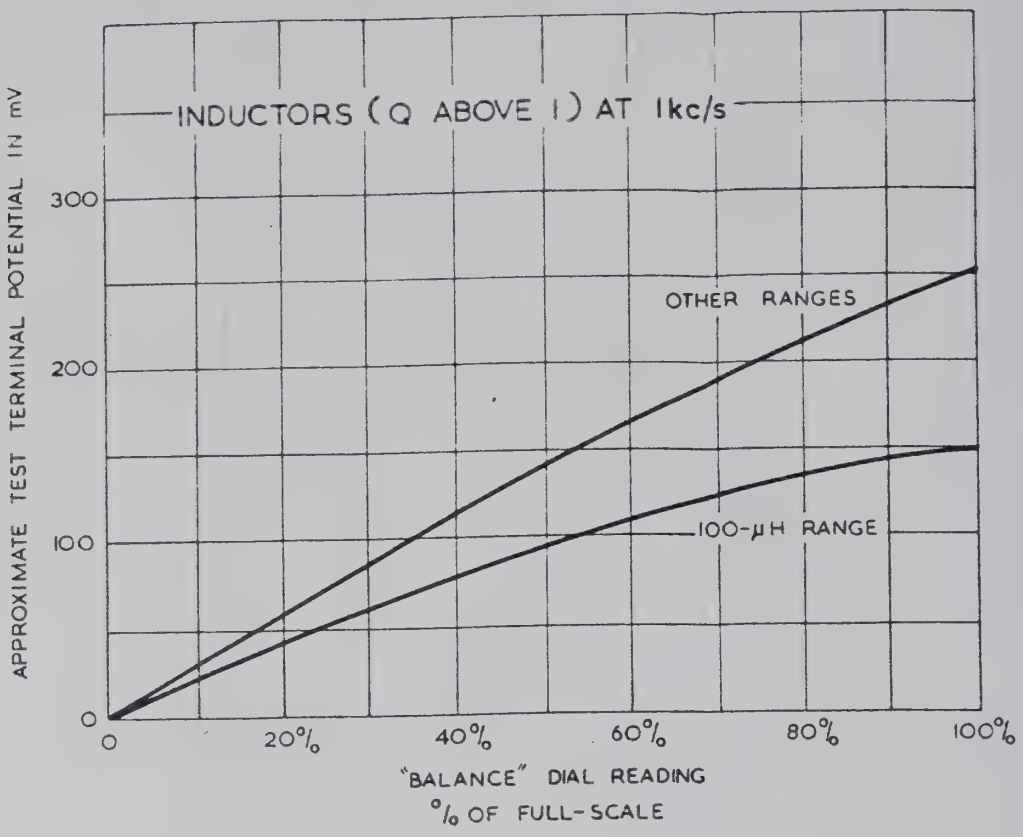


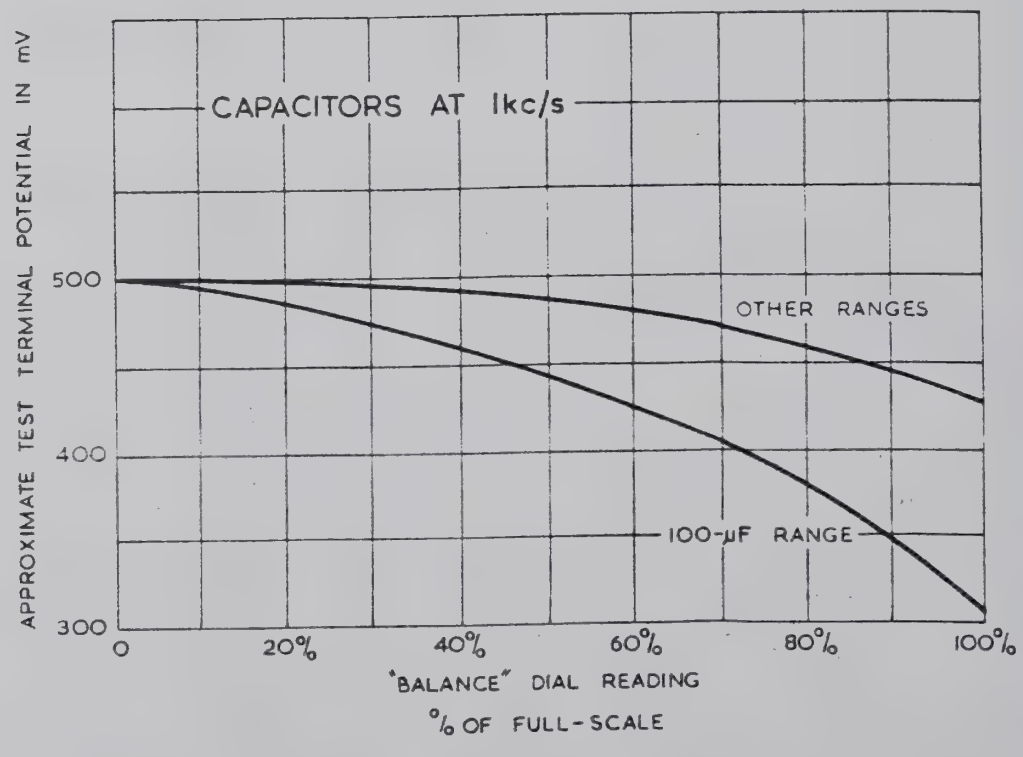


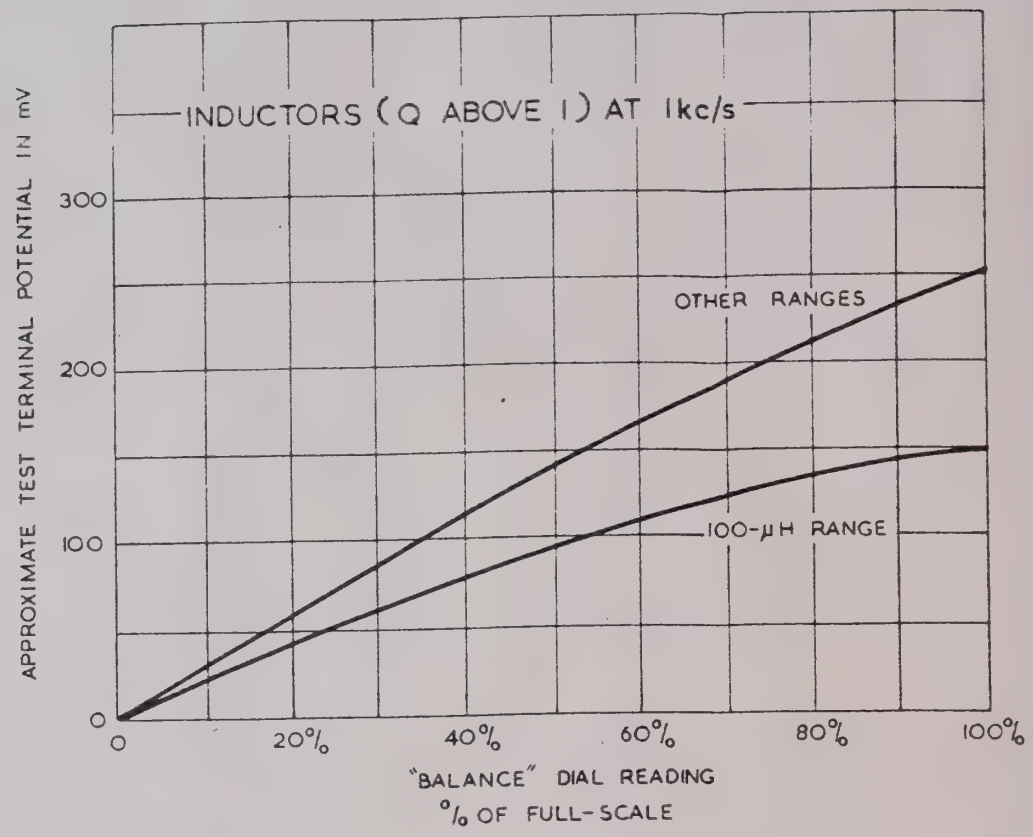


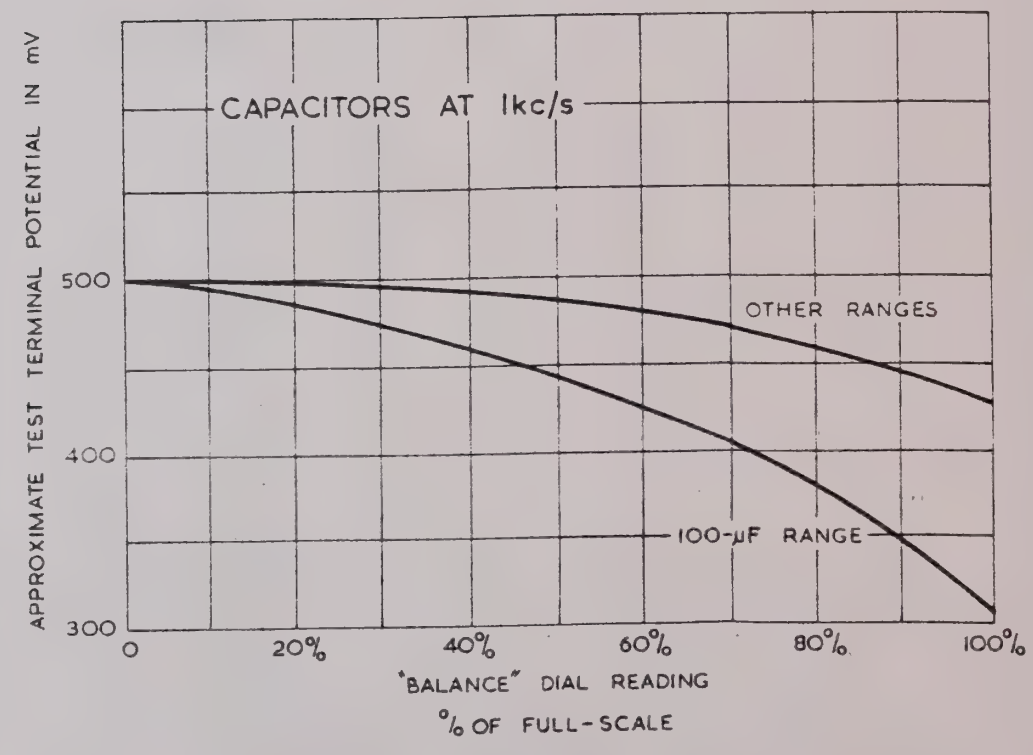
CHARTS OF TEST TERMINAL VOLTAGE AT BALANCE

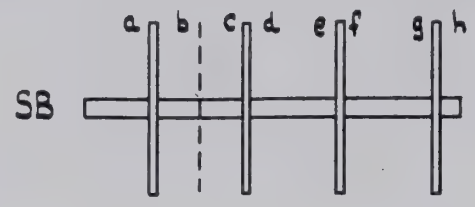
XD 30557

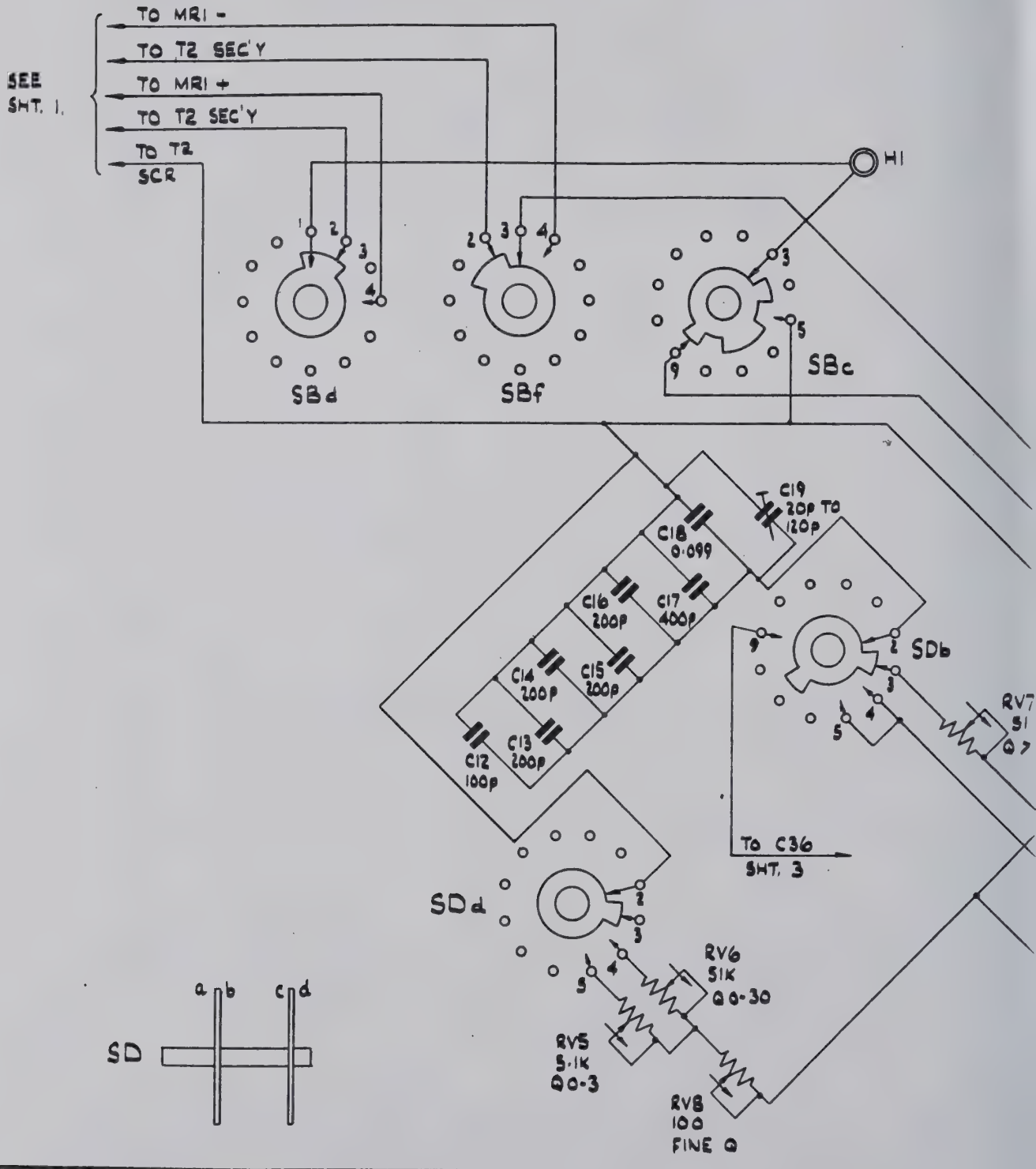

INDUCTORS (Q ABOVE 1) AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
300
200
100
0
OTHER RANGES
100-μH RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE


CAPACITORS AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
500
400
300
OTHER RANGES
100-μF RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE


INDUCTORS (Q ABOVE 1) AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
300
200
100
0
OTHER RANGES
100-μH RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE

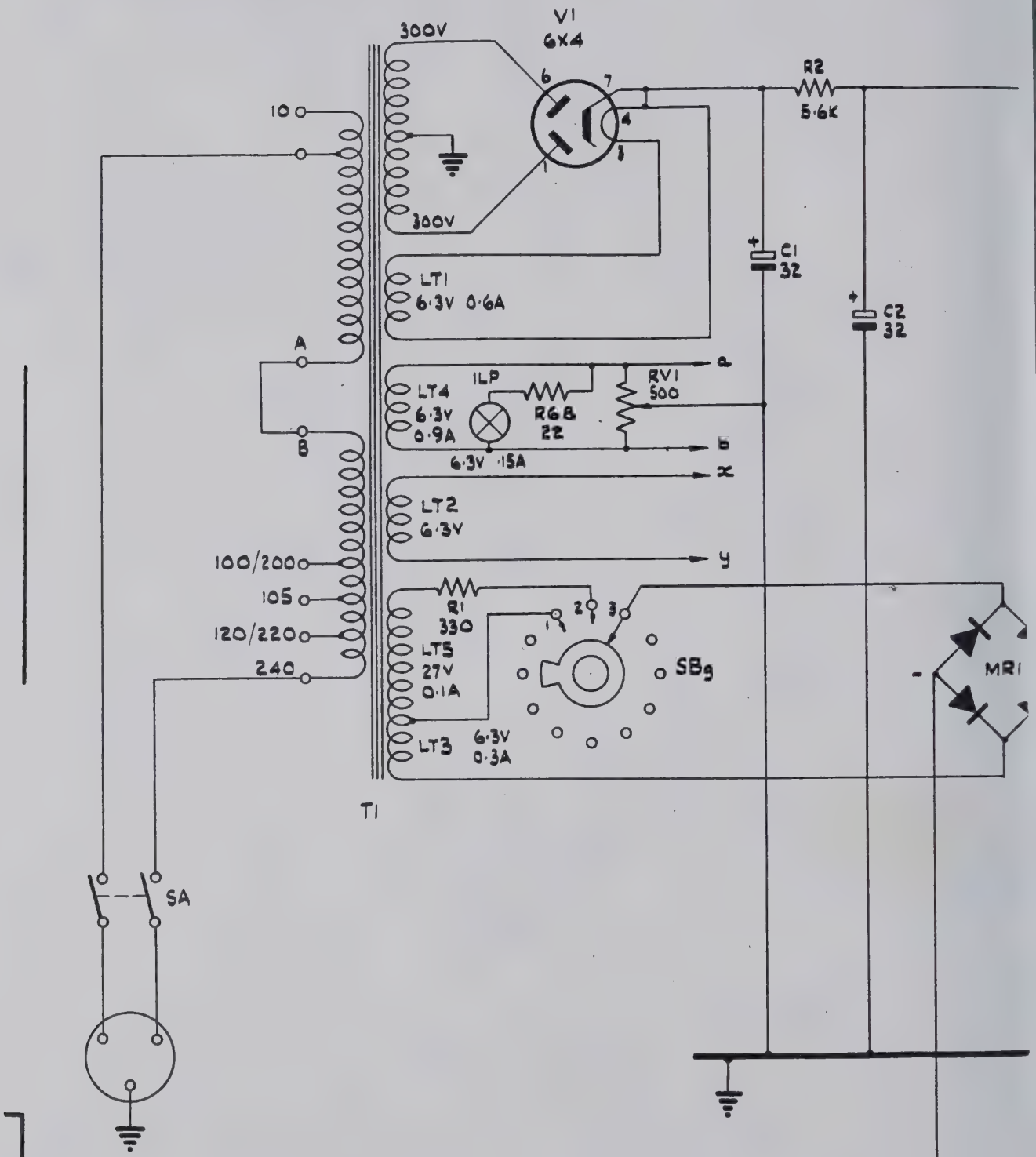

CAPACITORS AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
500
400
300
OTHER RANGES
100-μF RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE


a b c d e f g h
SB

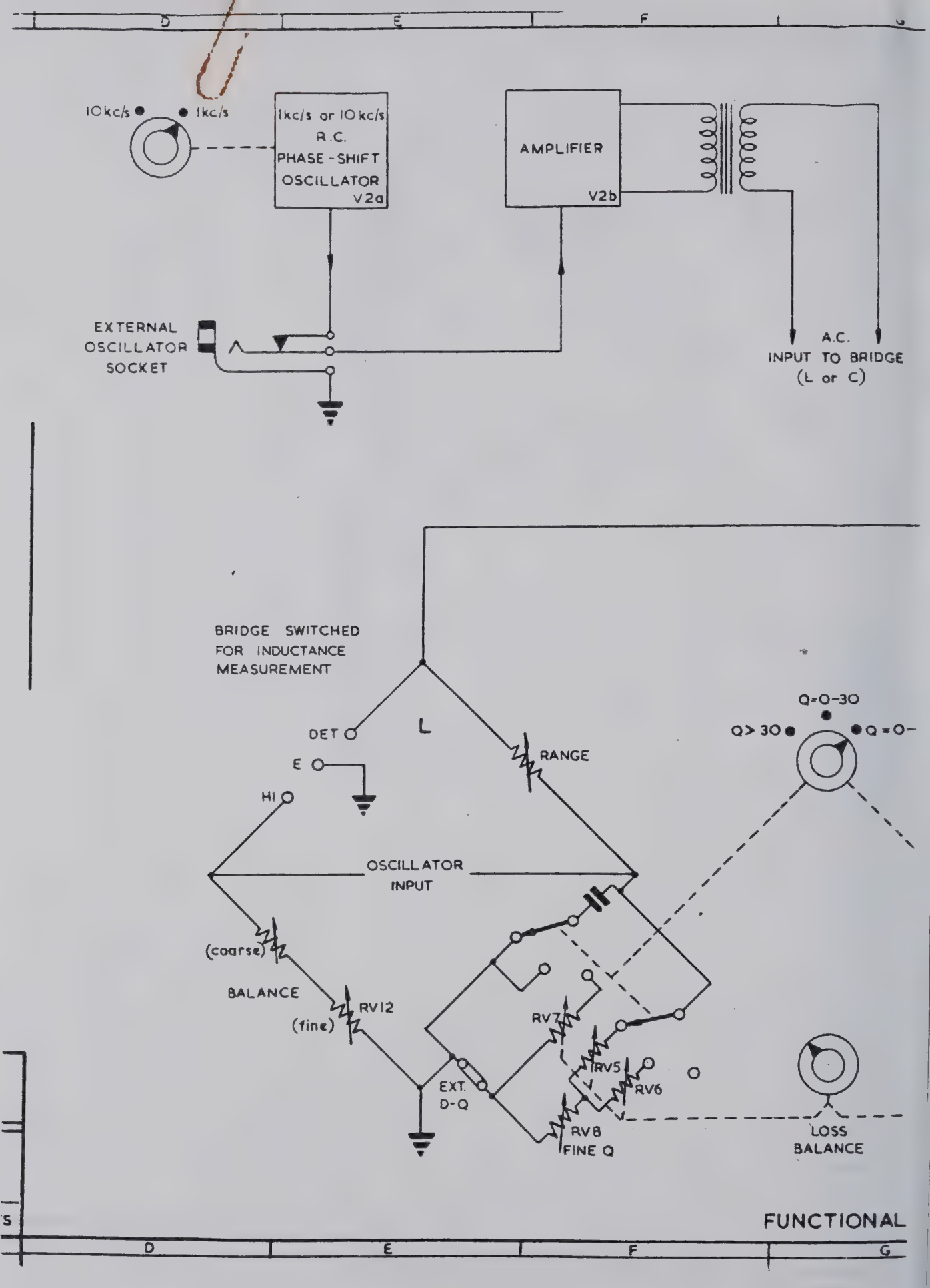

SEE SHT. 1.
TO MRI -
TO T2 SEC'Y
TO MRI +
TO T2 SEC'Y
TO T2 SCR
H1
SBd
SBf
SBc
C19 20P TO 120P
C18 0.099
C16 200P
C17 400P
C14 200P
C15 200P
C12 100P
C13 200P
SDb
RV7 5I Q 7
TO C36 SHT. 3
SDd
RV6 51K Q0-30
RV5 5.1K Q0-3
RV8 100 FINE Q

a b c d
SD

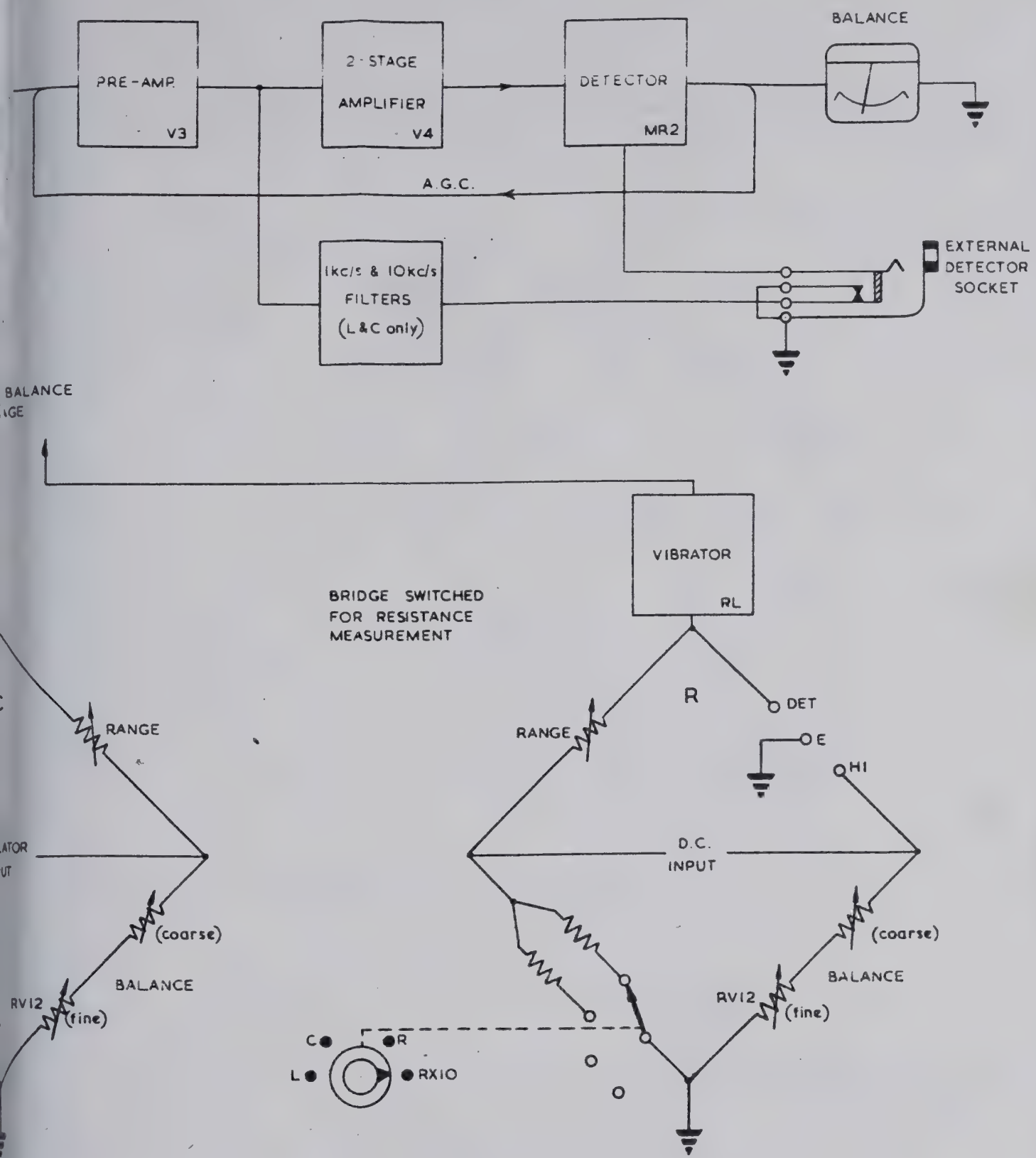
1/2


V1
6X4
300V
300V
10
A
B
100/200
105
120/220
240
LT1
6·3V 0·6A
LT4
6·3V
0·9A
ILP
R68
22
RV1
500
6·3V ·15A
LT2
6·3V
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
T1
R2
5·6K
C1
32
C2
32
SBg
MR1
SA
a
b
x
y

1/2


10kc/s
1kc/s
1kc/s or 10kc/s
R.C.
PHASE-SHIFT
OSCILLATOR
V2a
AMPLIFIER
V2b
EXTERNAL
OSCILLATOR
SOCKET
A.C.
INPUT TO BRIDGE
(L or C)
BRIDGE SWITCHED
FOR INDUCTANCE
MEASUREMENT
DET
E
HI
L
RANGE
Q=0-30
Q>30
Q=0-
OSCILLATOR
INPUT
(coarse)
BALANCE
(fine)
RV12
RV7
RV5
RV6
EXT.
D-Q
RV8
FINE Q
LOSS
BALANCE
FUNCTIONAL

1/2

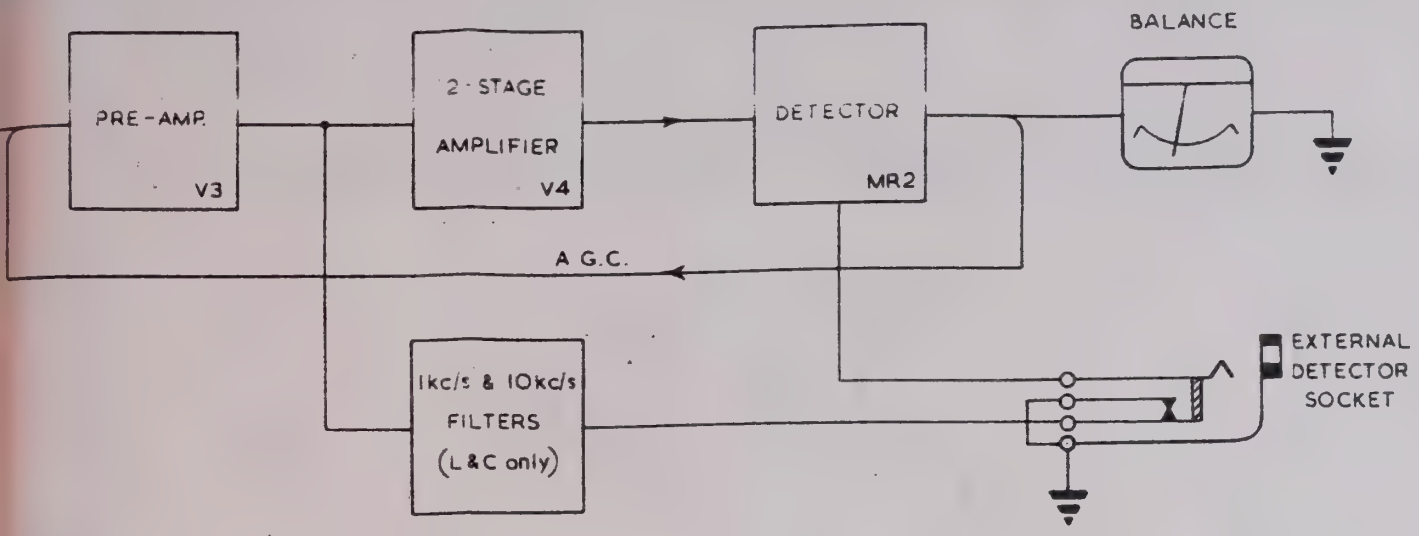


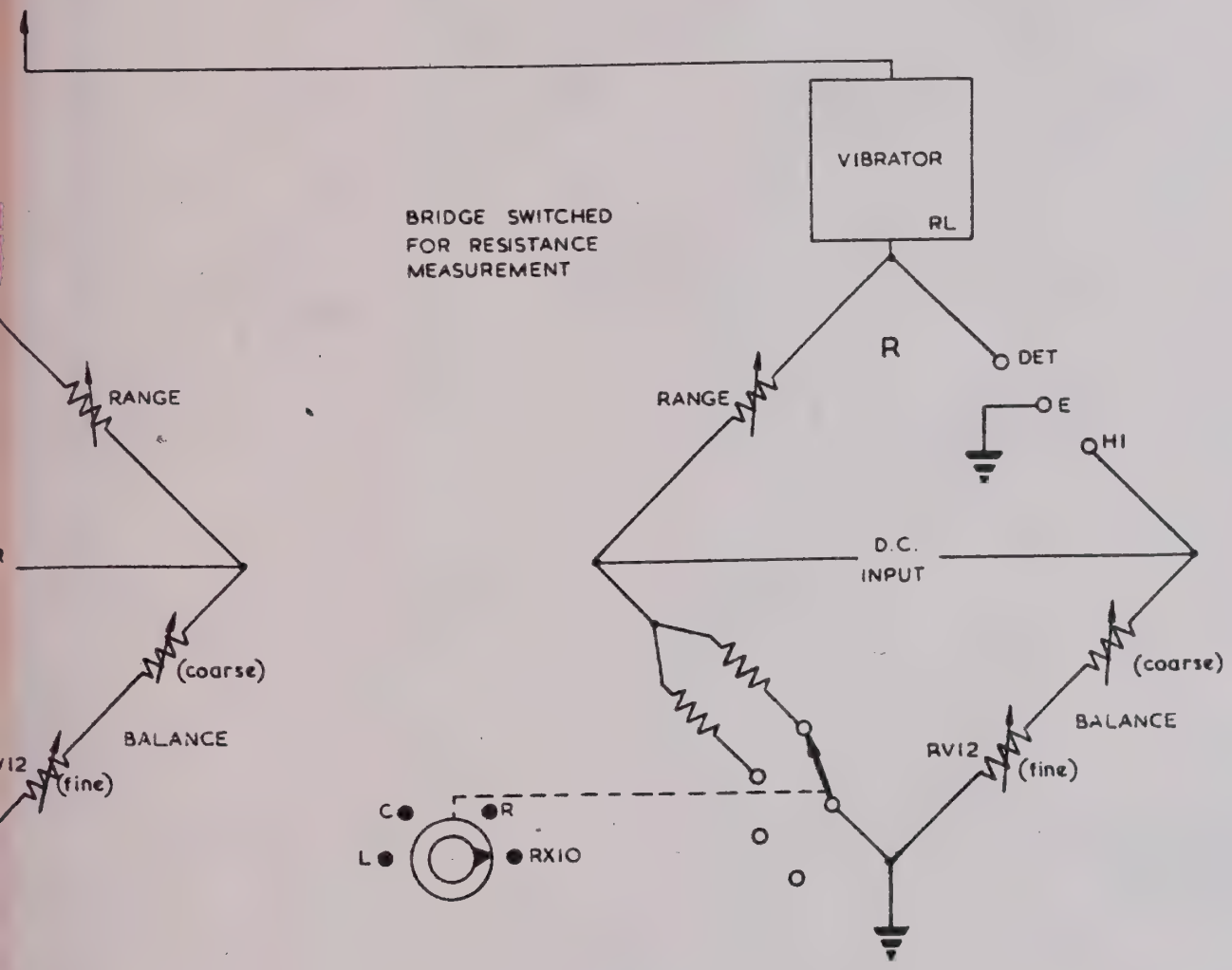
BRIDGE TYPE TF1313

XD 35166

J K L M

2/2



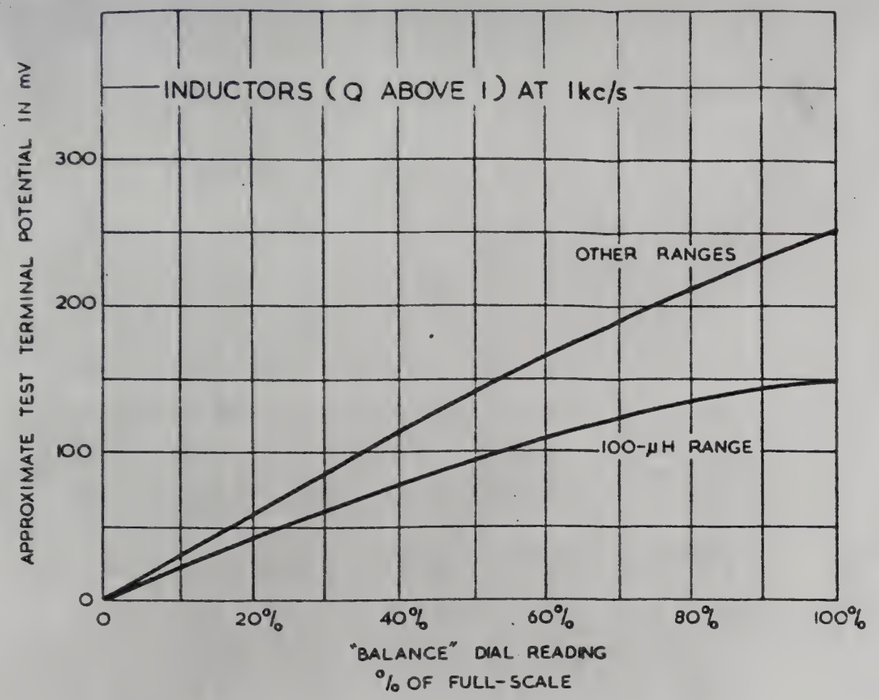


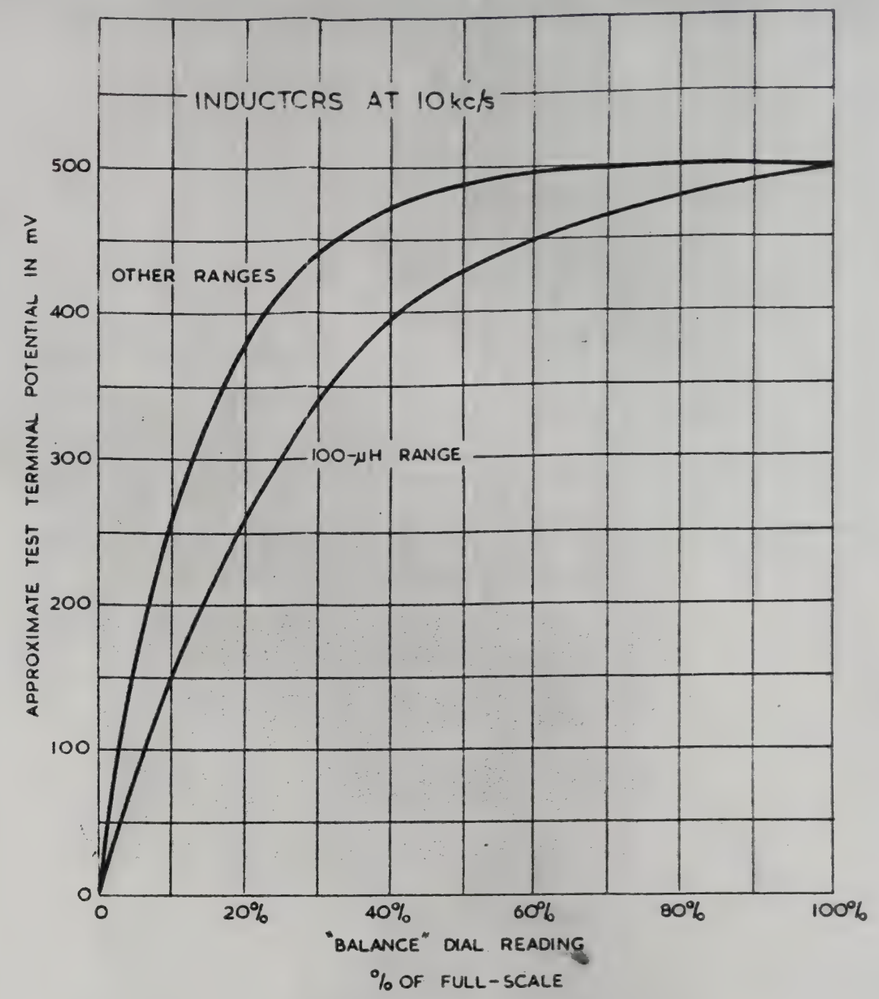
RIDGE TYPE TF1313

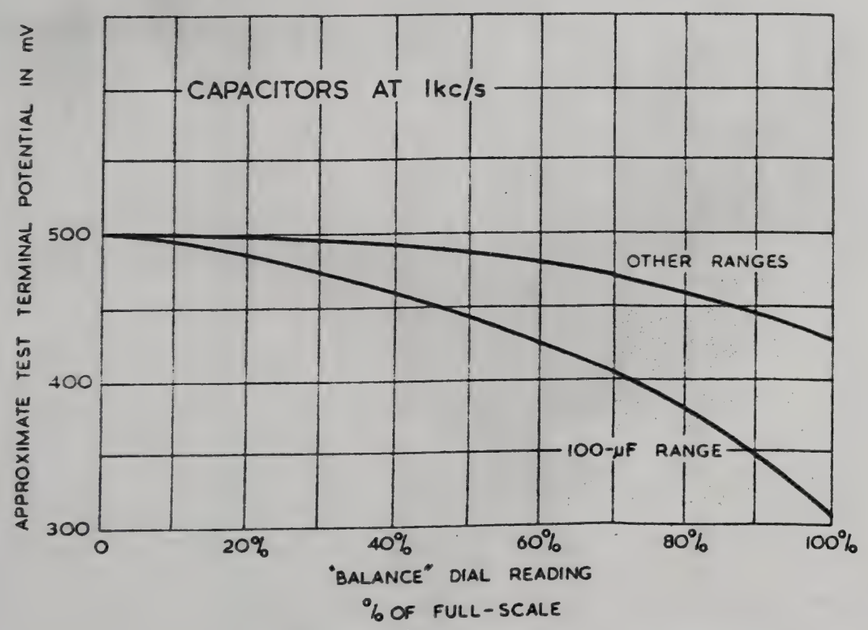
XD 35166

J K L M

2/2

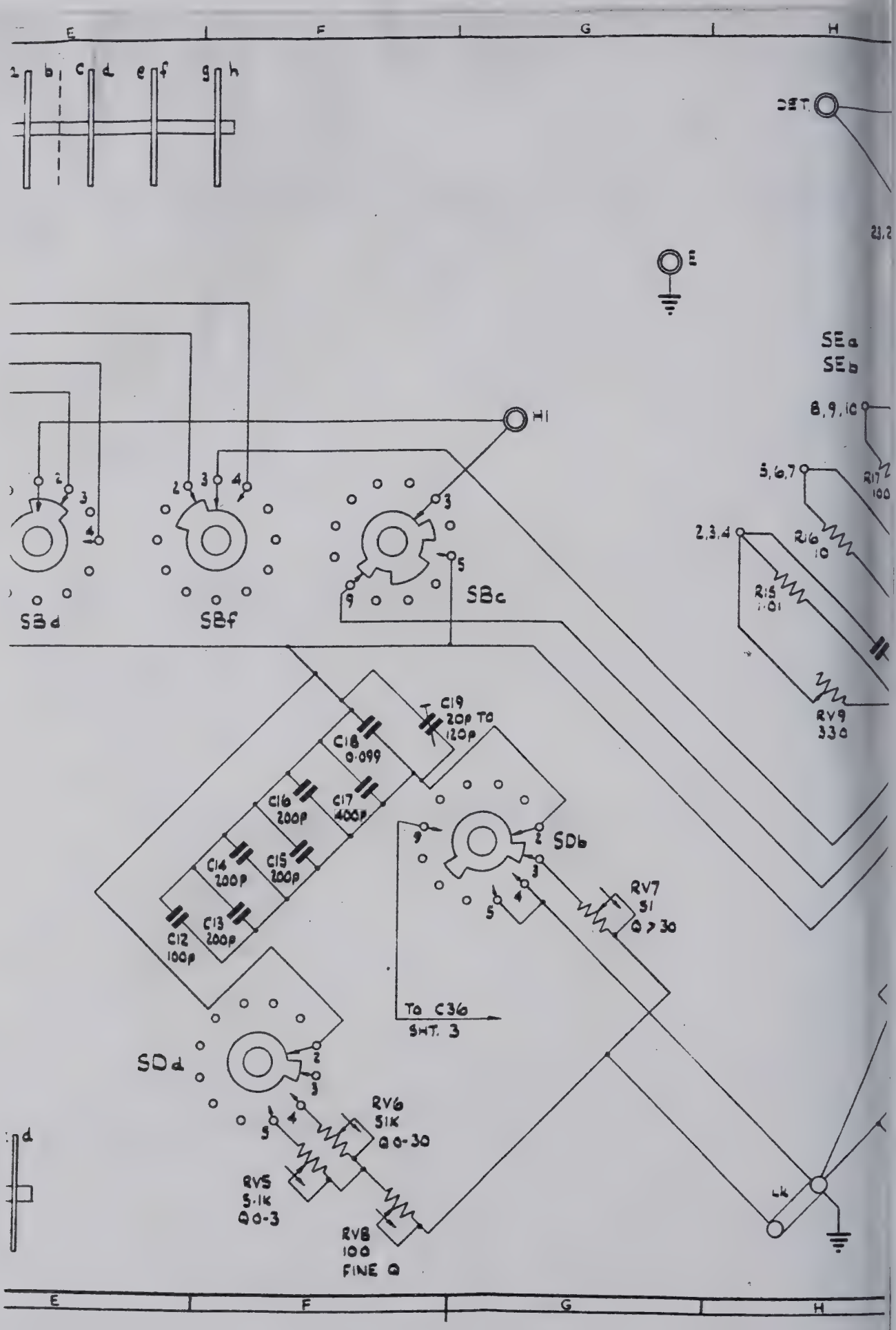


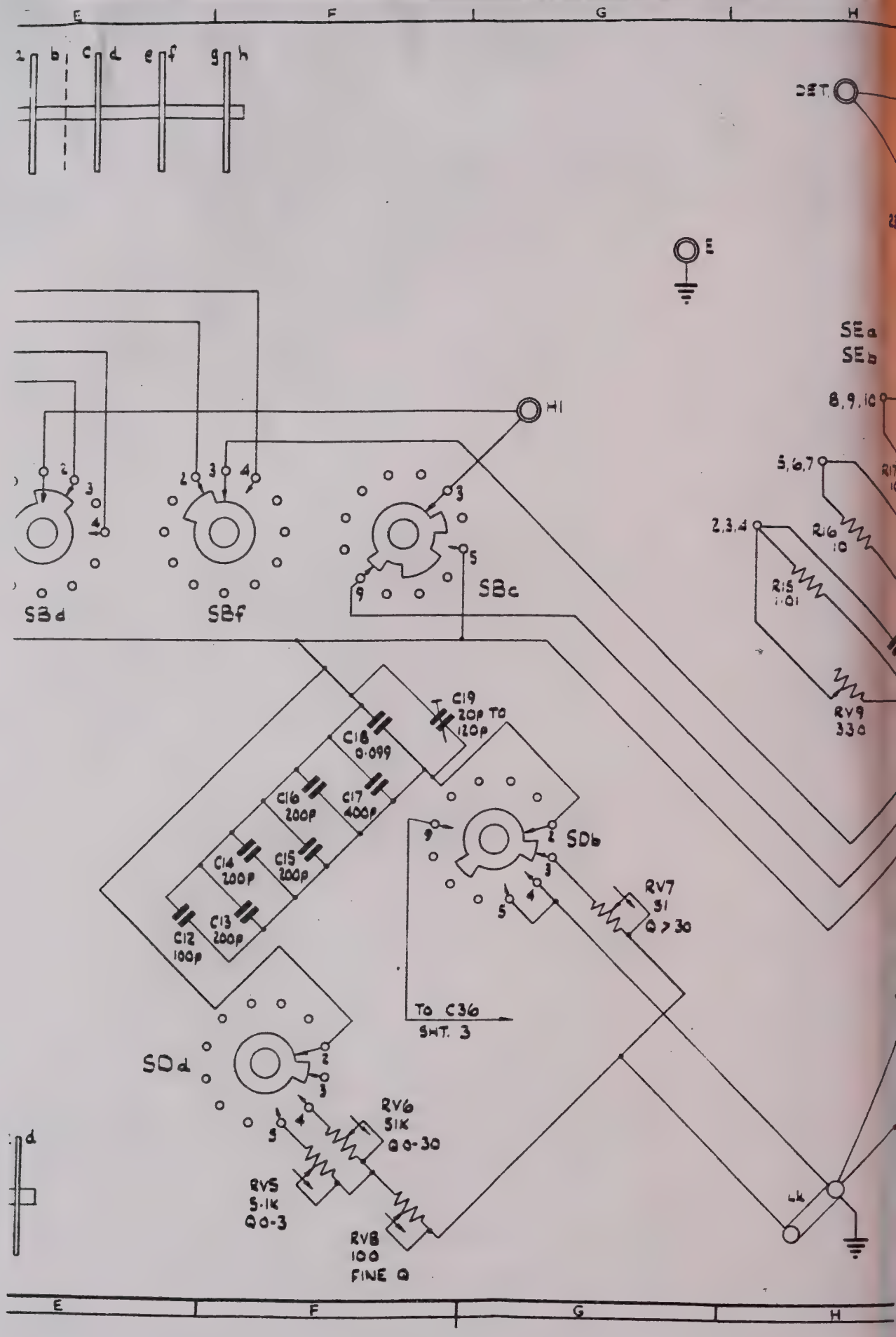


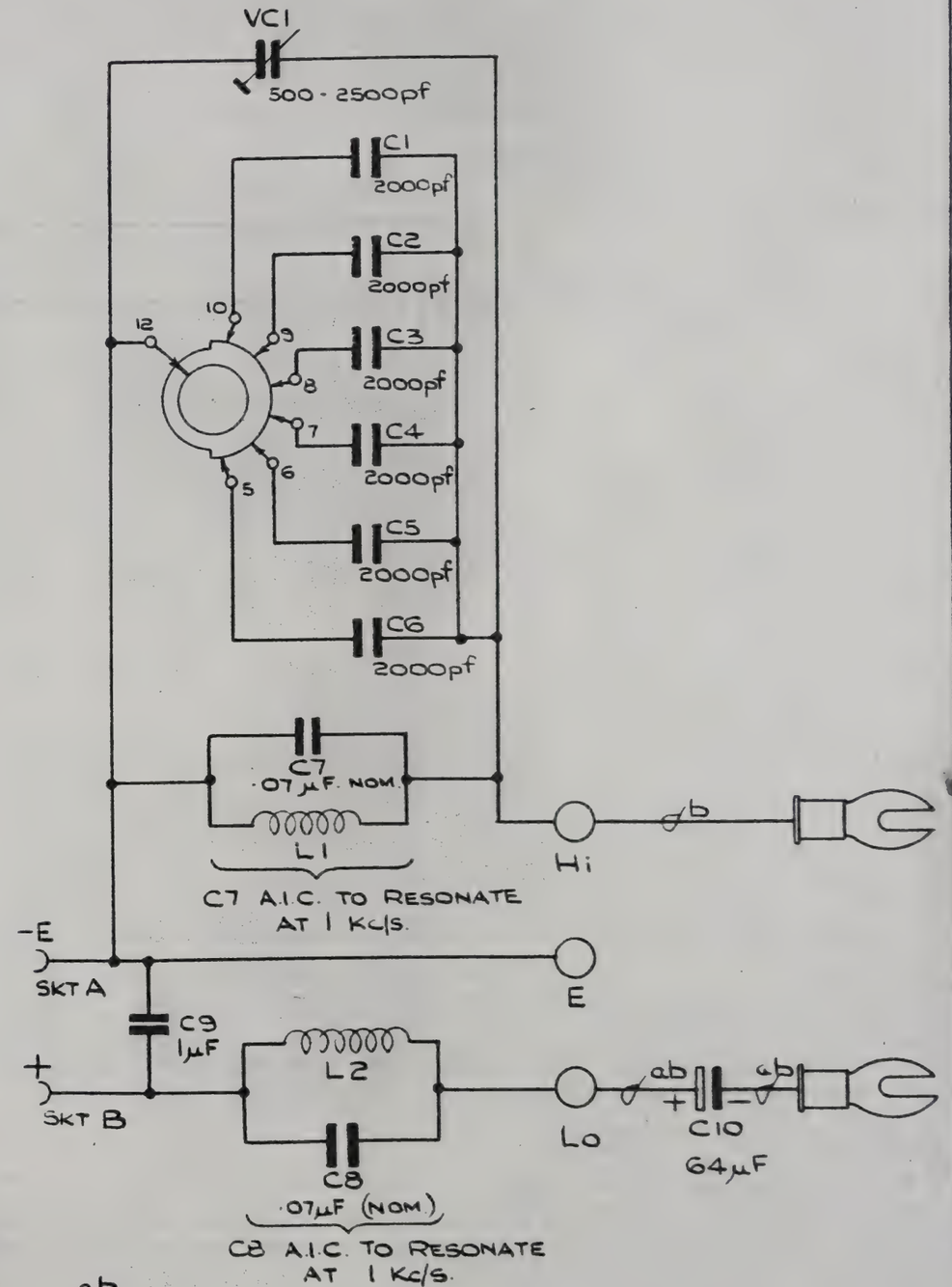


CHARTS OF TEST TERMINAL VOLTAGE AT BALANCE

XD 30557


E
F
G
H
a b c d e f g h
DET.
E
SEa
SEb
8,9,10
5,6,7
2,3,4
R17 100
R16 10
R15 1·01
RV9 330
H1
SBd
SBf
SBc
C19 20p TO 120p
C18 0·099
C16 200p
C17 400p
C14 200p
C15 200p
C12 100p
C13 200p
SDb
RV7 51 Q>30
TO C36 SHT. 3
SDd
RV6 51K Q 0-30
RV5 5·1K Q 0-3
RV8 100 FINE Q
Lk
d
E
F
G
H


E
F
G
H
a b c d e f g h
DET.
E
SEa
SEb
8,9,10
5,6,7
2,3,4
R16
10
R15
1·01
RV9
330
H1
SBd
SBf
SBc
C19
20p TO
120p
C18
0·099
C16
200p
C17
400p
C14
200p
C15
200p
C12
100p
C13
200p
SDb
RV7
31
Ω > 30
TO C36
SHT. 3
SDd
RV6
51K
Ω 0-30
RV5
5·1K
Ω 0-3
RV8
100
FINE Ω
4k
d
E
F
G
H



ab = 1c CABLE TO DEF 10

b = TC 20700/3

TITLE
DIRECT CURRENT CHOKE ADAPTOR CIRCUIT DIAGRAM.

DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK LIST	DRAWING Nº
J PORTER	22-10-59	IT	DW	T.D.S.	TD 31304	TM 6113	XC 31308

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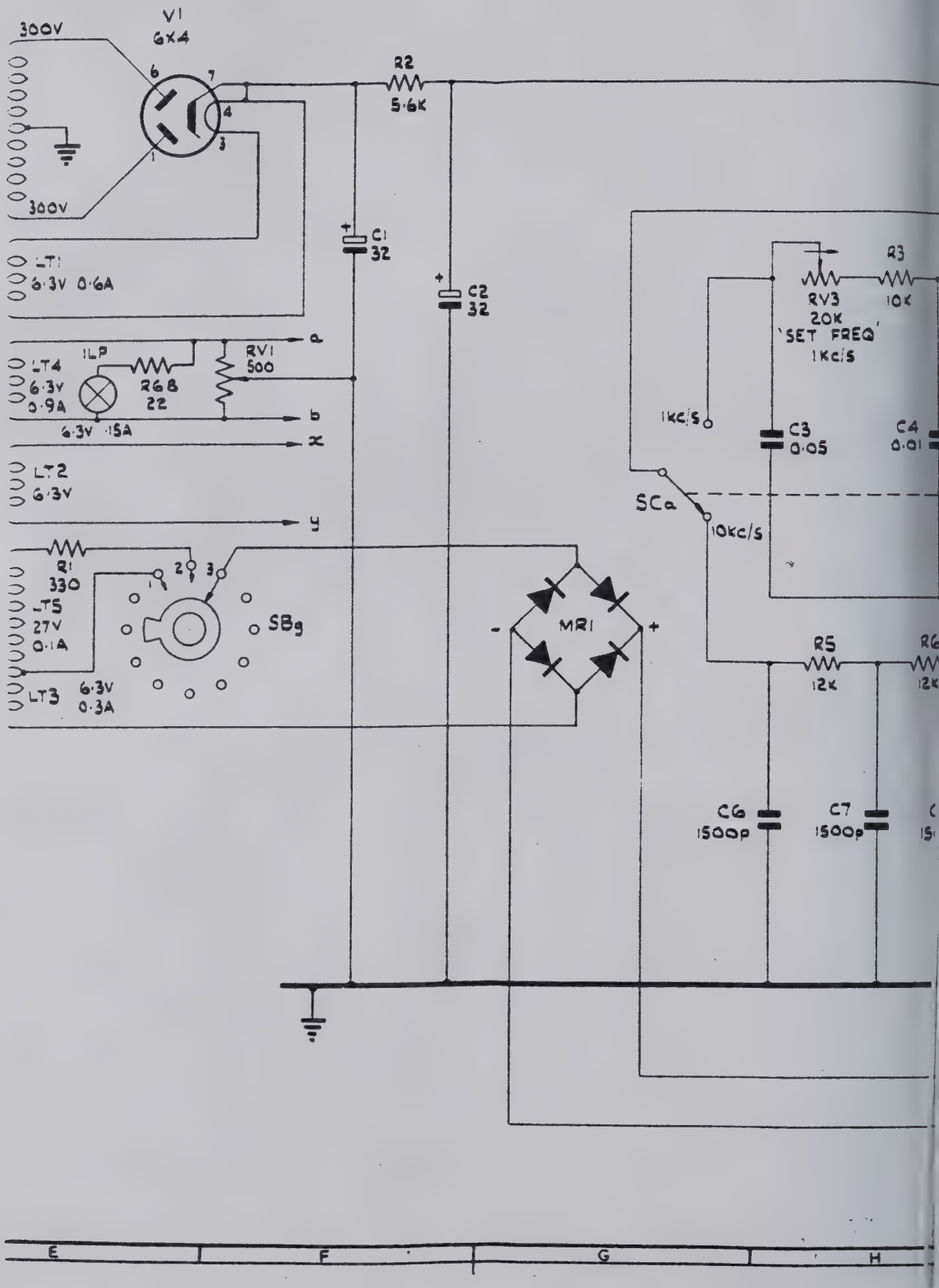
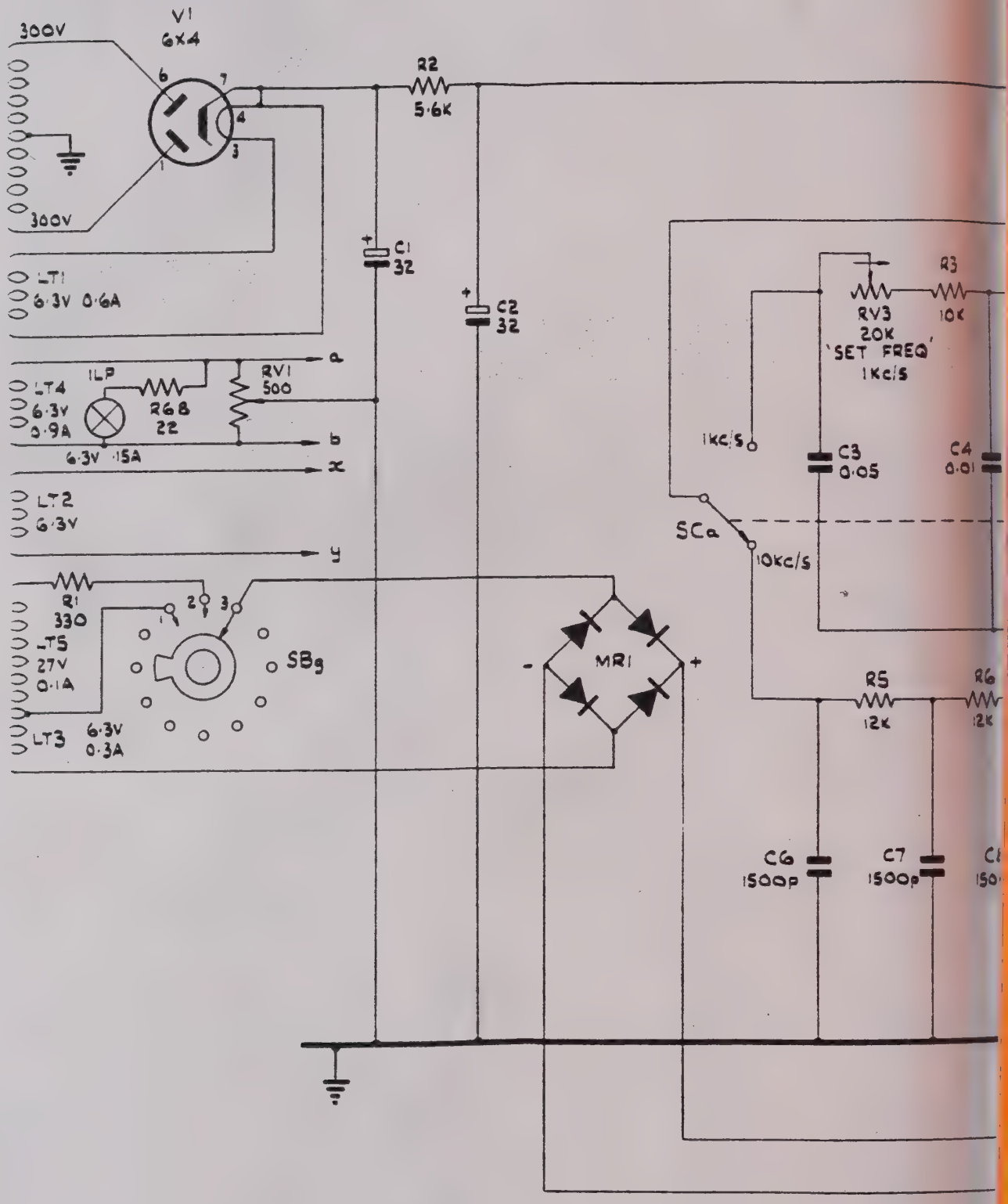
SHEET OF SHEETS


V1
6X4
300V
300V
LT1
6·3V 0·6A
R2
5·6K
C1
32
C2
32
LT4
6·3V
0·9A
ILP
R68
22
RV1
500
6·3V ·15A
a
b
x
LT2
6·3V
y
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
SBg
MR1
R3
RV3
20K
'SET FREQ'
1Kc/s
10K
1kc/s
C3
0·05
C4
0·01
SCa
10kc/s
R5
12K
C6
1500p
C7
1500p
E
F
G
H


300V
V1
6X4
6
7
4
3
1
300V
R2
5·6K
C1
32
C2
32
LT1
6·3V 0·6A
LT4
6·3V
0·9A
ILP
R68
22
RV1
500
a
b
6·3V ·15A
x
LT2
6·3V
y
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
1
2
3
SBg
MR1
-
+
R3
RV3
20K
'SET FREQ'
1kc/s
10K
1kc/s
C3
0·05
C4
0·01
SCa
10kc/s
R5
12K
R6
12K
C6
1500p
C7
1500p

NOTE :- WIRING IN MINIATURE CABLE Nº 1C SHOWN THUS :- ≡≡∫ˣ≡≡

TO H.T. SHT. 1

TO SDb TAC 9

TO SBb TAC 8

TO SBb TAC 10

TO SBb TAC 12

TO SBb TAC 6

C36 0.003

R52 68K

C37 470p

C38 470p

R51 1M

R46 150K

R47 150K

R48 150K

R49 150K

R50 1M

RL

C32 0.1

C34 0.1

C33 0.1

C35 0.1

SBh

RV2 500

R53 10M

R54 470K

R55 220K

C39 0.01

R58 1M

V3 EF86

C40 8

C41 120p S.I.C.

L1

C42 0.01

L2

R56 330K

R57 2.2K

C44 0.01

C43 0.003

R61 33K

R63 4.7K

R62 150K

C45 0.05

C46 0.003

V4 12AX7

R66 10M

MR2 OA73

R60 1.5K

R65 1M

R67 100K

R59 4.7M

R64 100

RV13 1.5K

M1 100μA

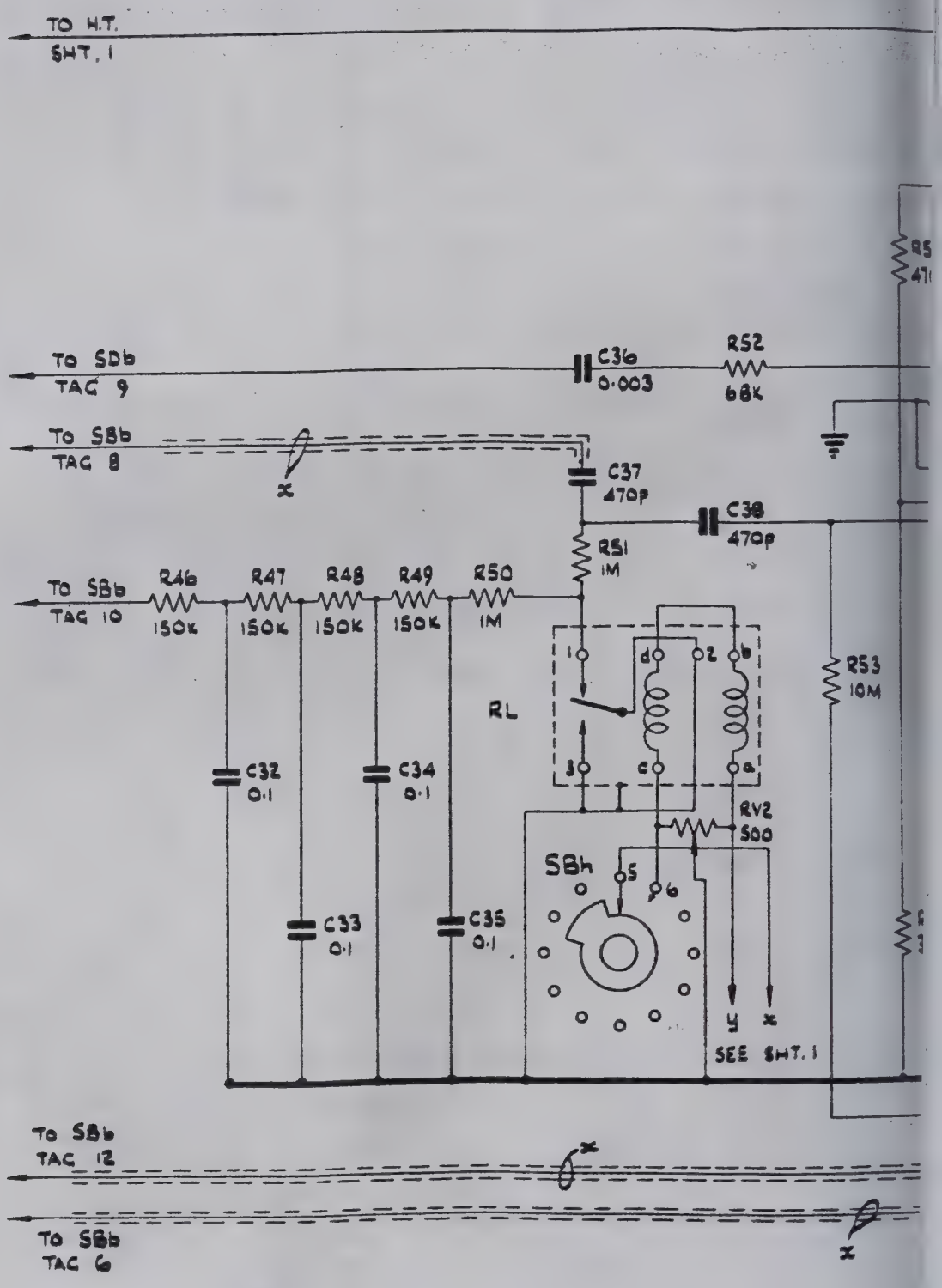
C47 1

SEE SHT. 1

XD 32020

D E F G

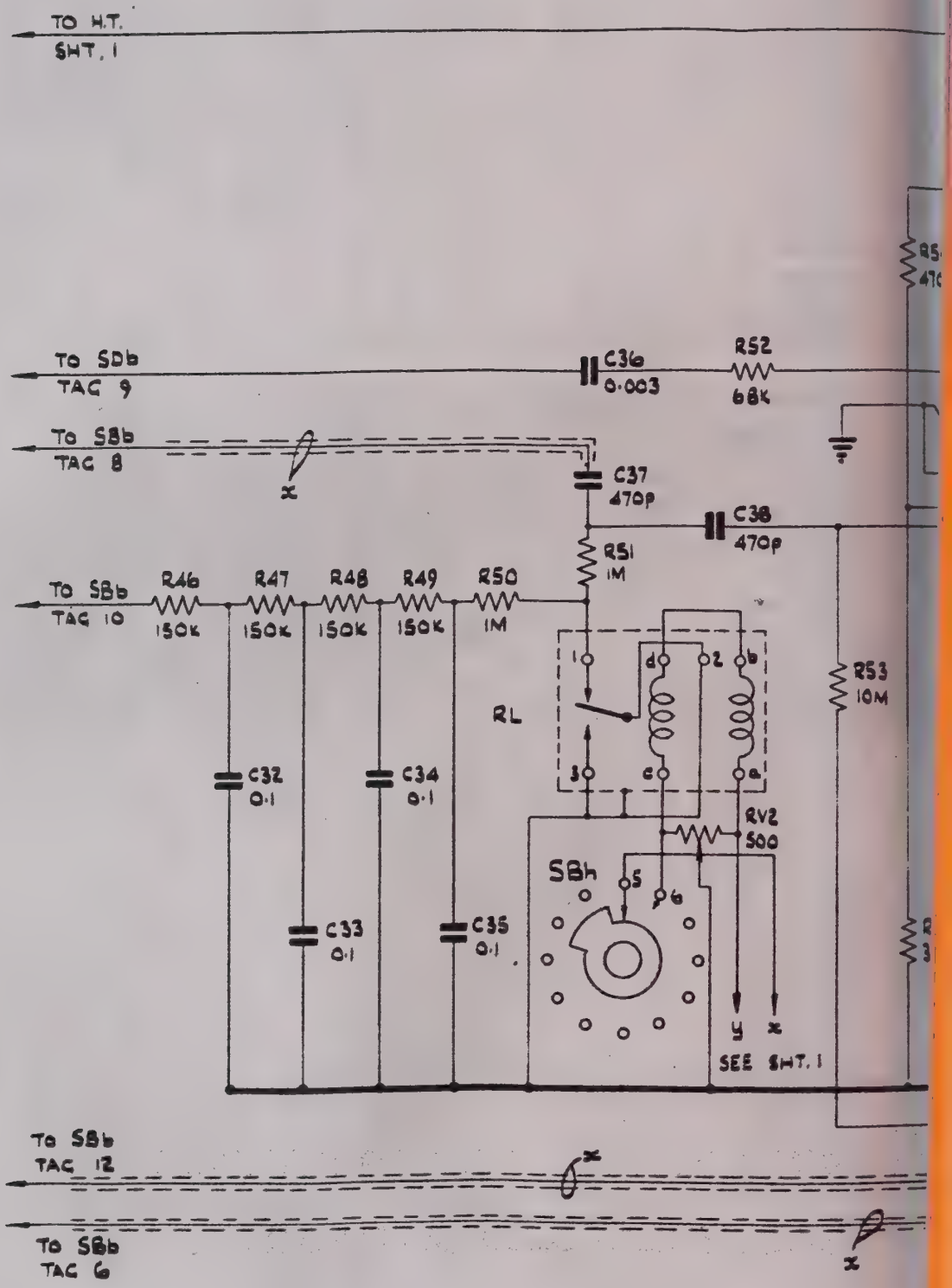
NOTE :- WIRING IN MINIATURE CABLE N° IC SHOWN THUS :- x



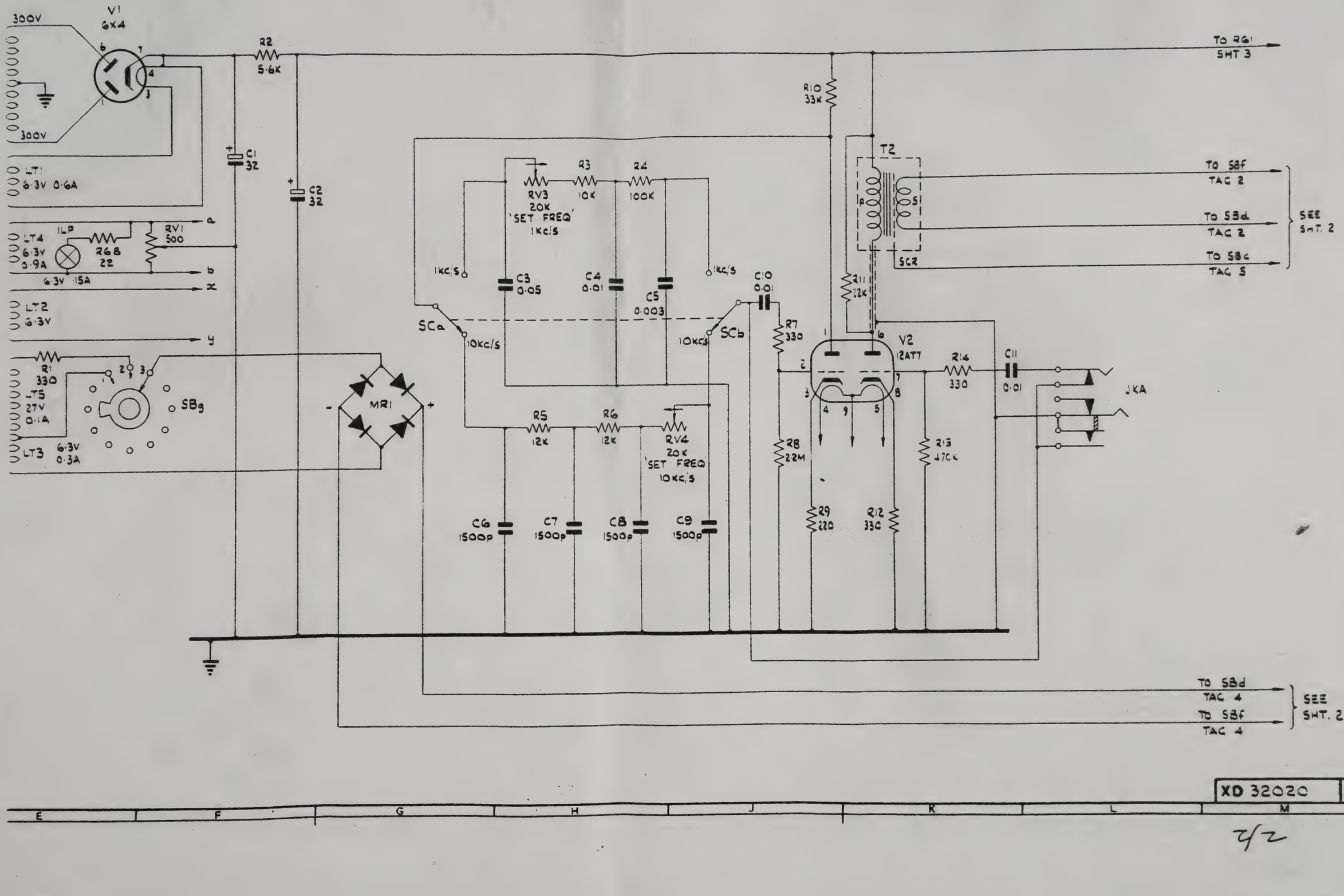
D E F G

D E F G

NOTE :- WIRING IN MINIATURE CABLE Nº 1C SHOWN THUS :- x



D E F G


300V
V1
6X4
300V
LT1
6·3V 0·6A
C1
32
C2
32
R2
5·6K
LT4
6·3V
0·9A
ILP
6·3V ·15A
R68
22
RV1
500
a
b
x
LT2
6·3V
y
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
SBg
MR1
1kc/s
RV3
20K
'SET FREQ'
1Kc/s
R3
10K
R4
100K
C3
0·05
C4
0·01
C5
0·003
1kc/s
SCa
10kc/s
SCb
10kc/s
C10
0·01
R7
330
R5
12K
R6
12K
RV4
20K
'SET FREQ'
10Kc/s
C6
1500p
C7
1500p
C8
1500p
C9
1500p
R10
33K
T2
P
S1
SCR
R11
12K
V2
12AT7
R14
330
C11
0·01
JKA
R8
22M
R9
220
R12
330
R13
470K
TO RG1
SHT 3
TO SBf
TAC 2
TO SBd
TAC 2
TO SBc
TAC 5
SEE
SHT. 2
TO SBd
TAC 4
TO SBf
TAC 4
SEE
SHT. 2

XD 32020

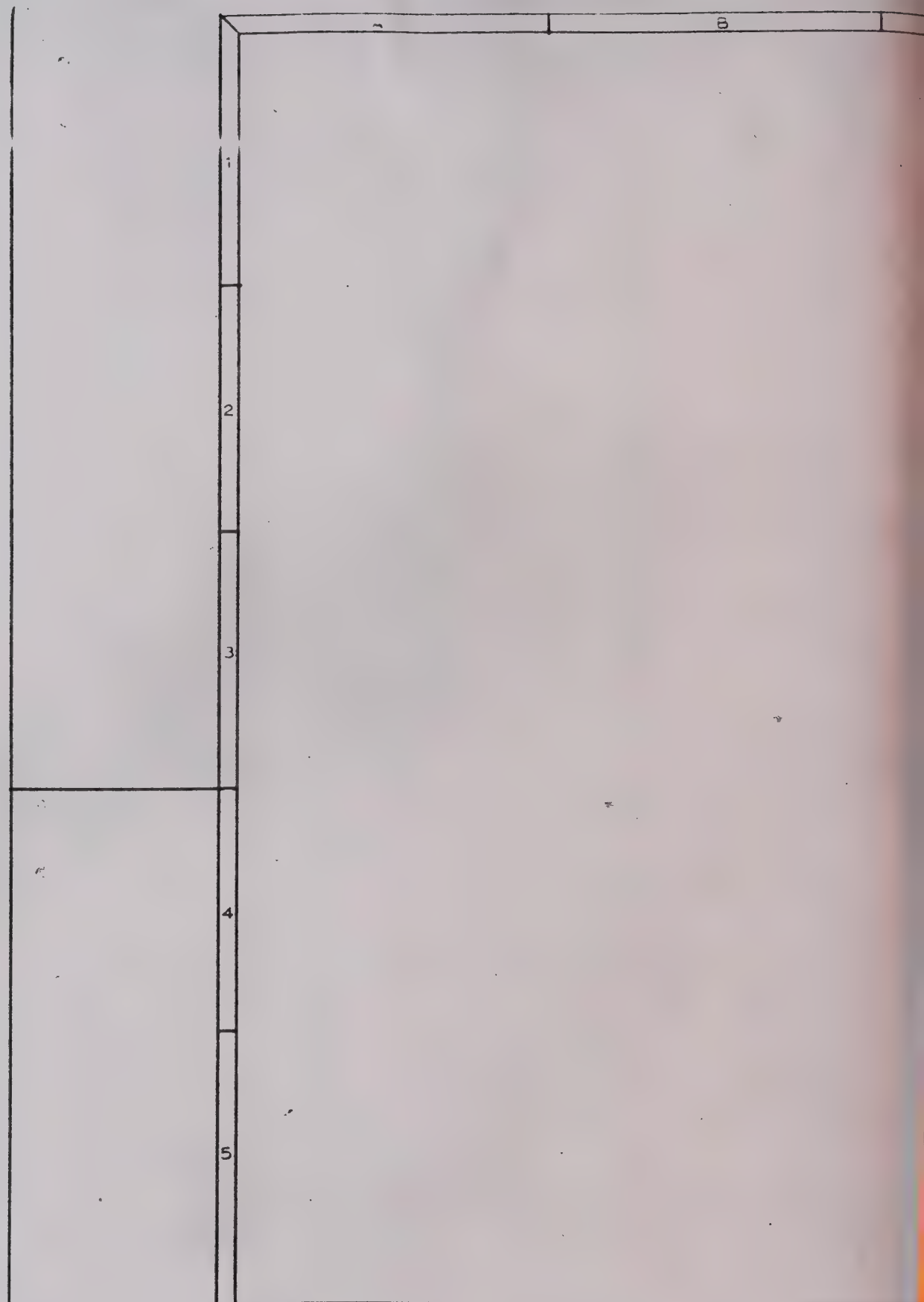
2/2

TITLE

DIRECT CURRENT CHOKE ADAPTOR CIRCUIT

DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK L
J. PORTER	22-10-59	IT	DW	T.D.S.	TD 31304	TM 61

MARCONI INSTRUMENTS LTD.

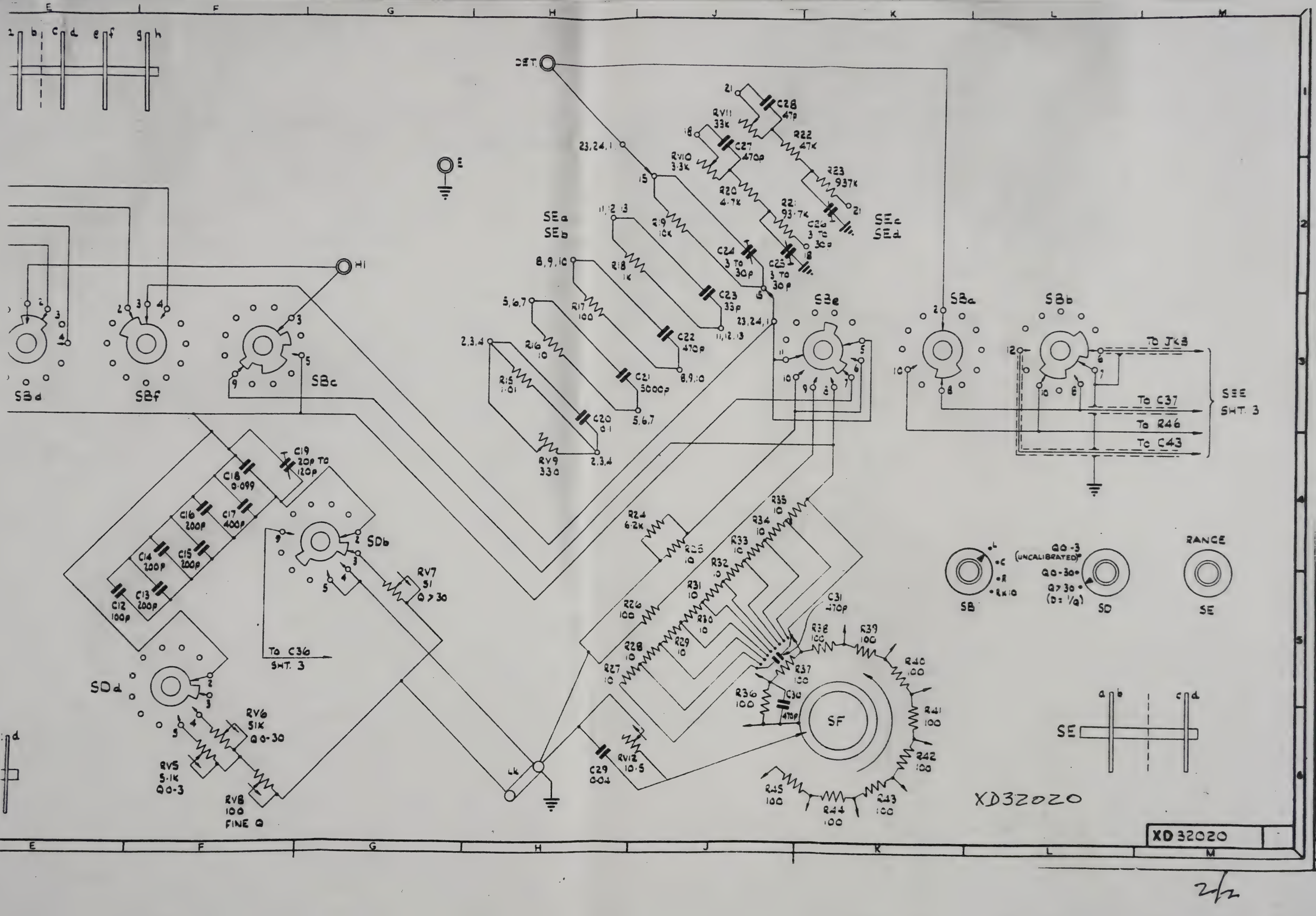


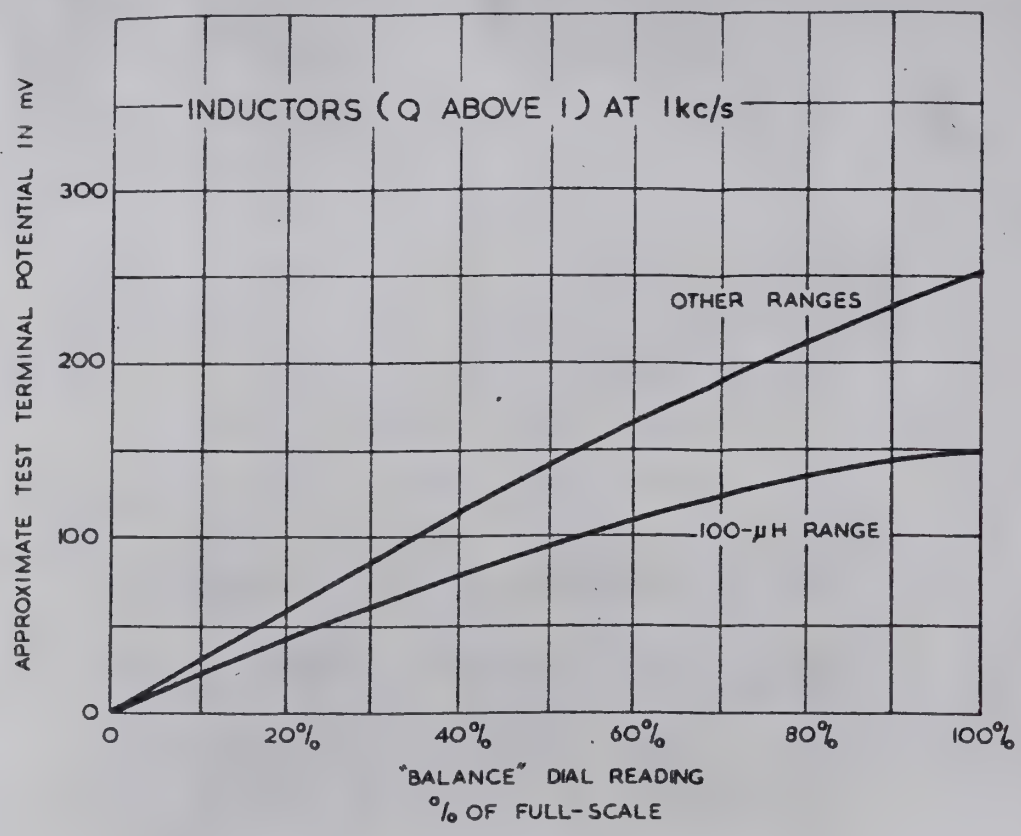
TITLE

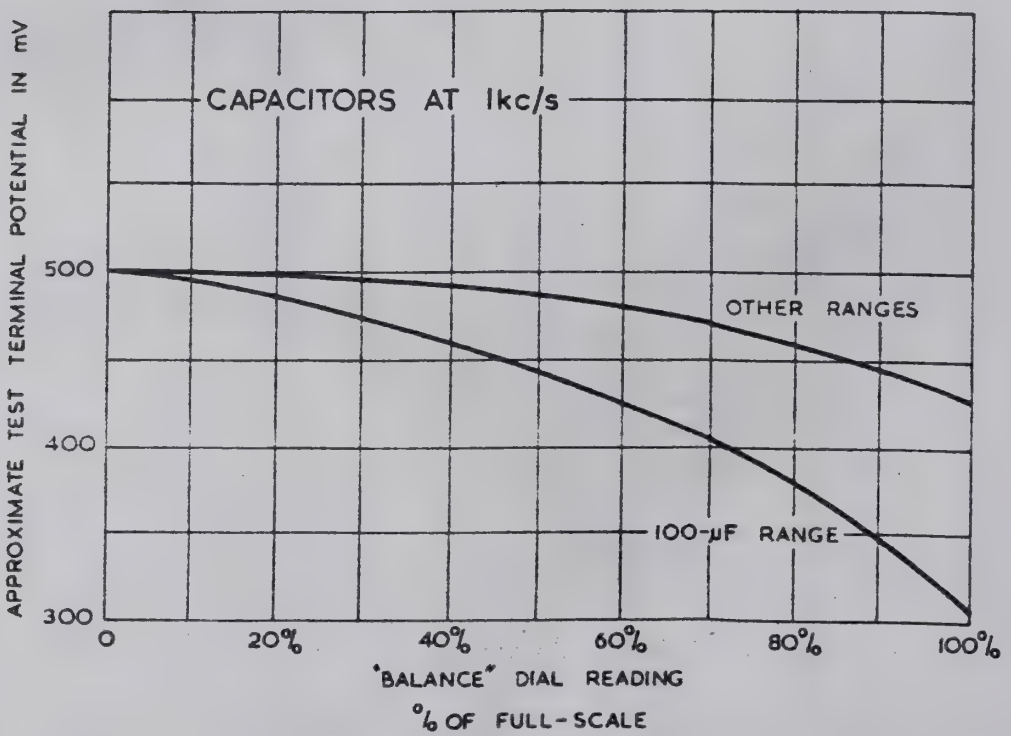
DIRECT CURRENT CHOKE ADAPTOR CIRCUIT

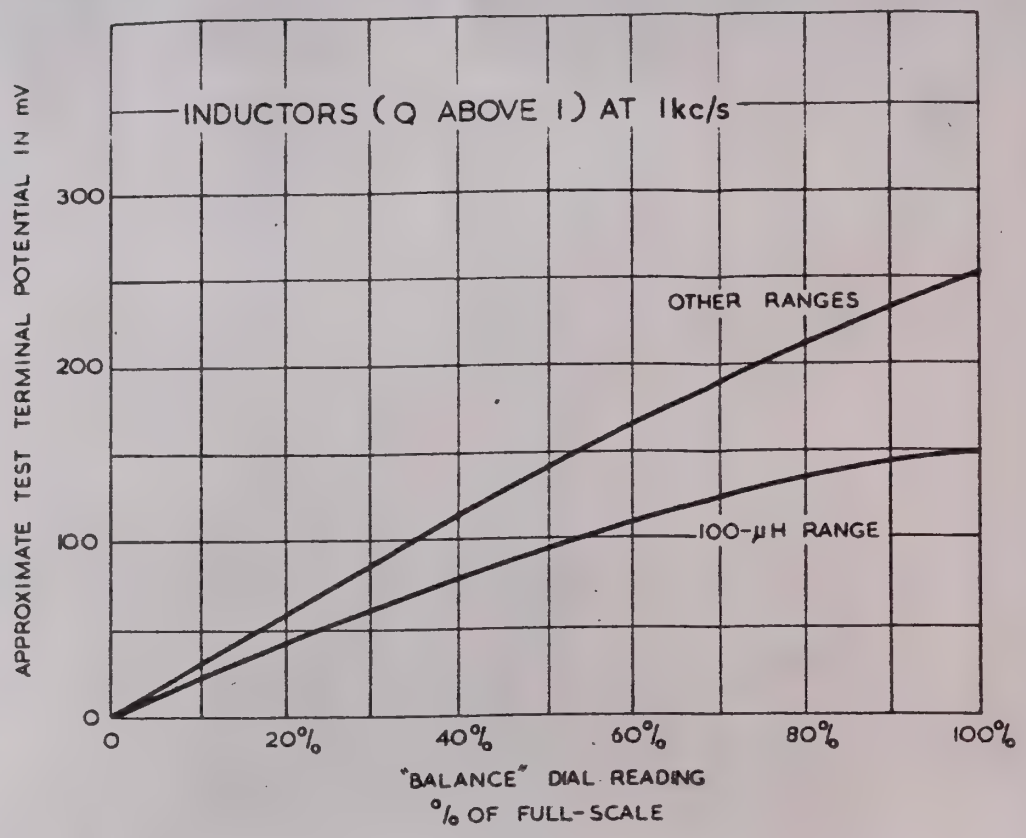
DRAWN	DATE	CHKD	APPD	TRCD	ASSEMBLY	STOCK
J PORTER	22-10-59	IT	DW	T.D.S.	TD 31304	TM 6

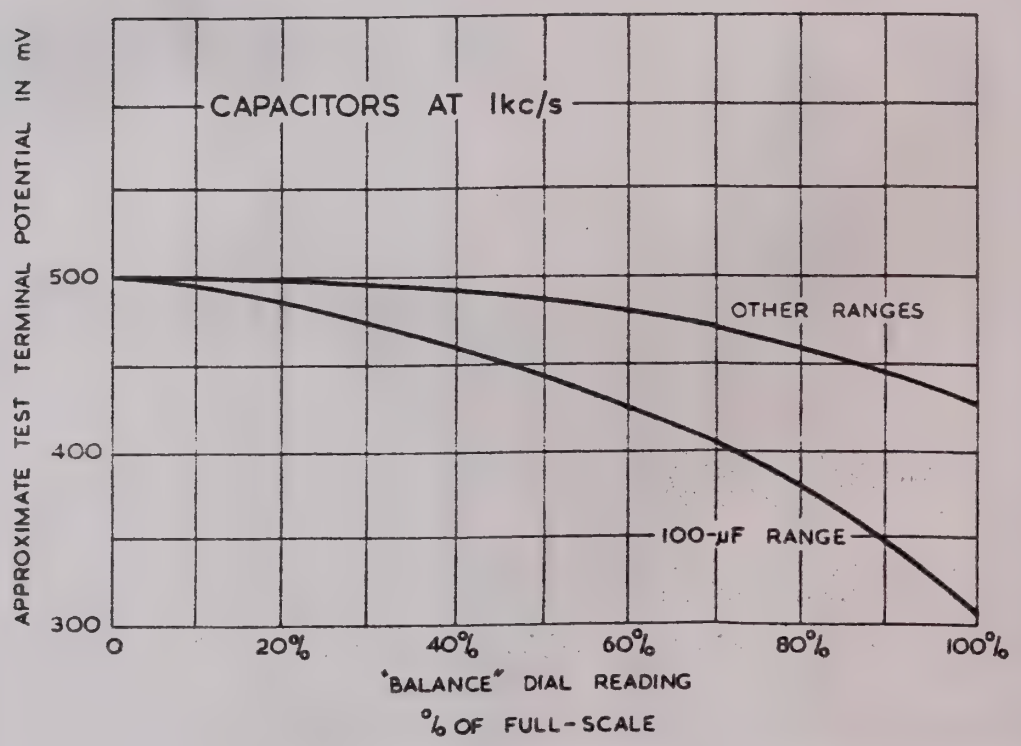
MARCONI INSTRUMENTS LTD.

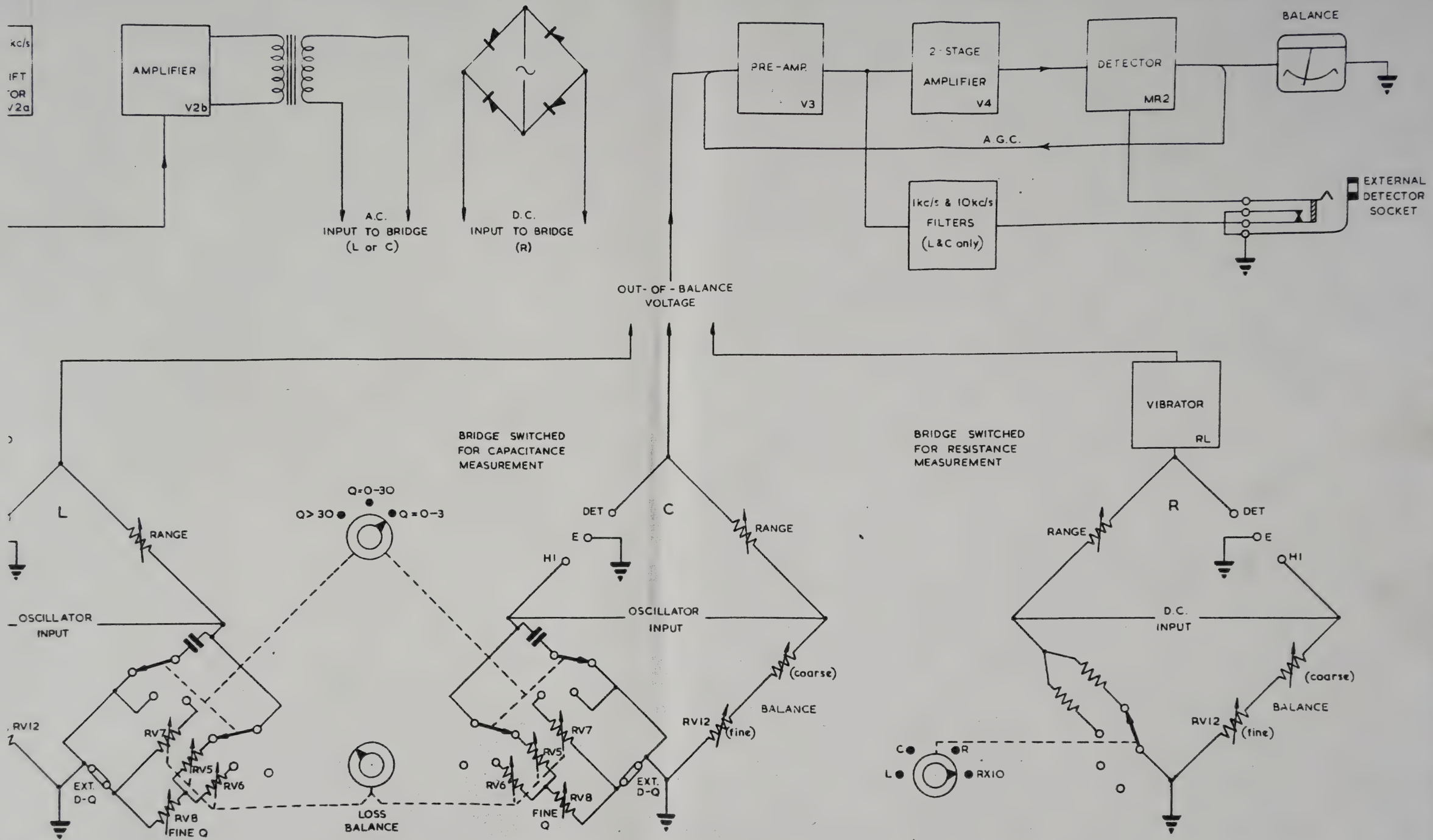

DET
E
SEa
SEb
SEc
SEd
SBa
SBb
SBc
SBd
SBe
SBf
SDa
SDb
SDd
SF
HI
LK
21
18
23,24,1
15
11,12,13
8,9,10
5,6,7
2,3,4
C28 47p
RV11 33k
R22 47k
C27 470p
RV10 3.3k
R23 937k
R20 4.7k
R21 93.7k
C26 3 TO 30p
C24 3 TO 30p
C25 3 TO 30p
R19 10k
R18 1k
R17 100
R16 10
R15 1.01
C23 33p
C22 470p
C21 5000p
C20 0.1
RV9 330
C19 20p TO 120p
C18 0.099
C16 200p
C17 400p
C14 200p
C15 200p
C13 200p
C12 100p
RV7 51 Q>30
RV6 51K Q 0-30
RV5 5.1K Q 0-3
RV8 100 FINE Q
TO C36 SHT. 3
R24 6.2K
R25 10
R26 100
R27 10
R28 10
R29 10
R30 10
R31 10
R32 10
R33 10
R34 10
R35 10
C29 0.04
RV12 10.5
C31 470p
R36 100
C30 470p
R37 100
R38 100
R39 100
R40 100
R41 100
R42 100
R43 100
R44 100
R45 100
TO J<3
TO C37
TO R46
TO C43
SEE SHT. 3
Q0-3 (UNCALIBRATED)
Q0-30
Q>30 (D=1/Q)
RANGE
L
C
R
Rx10
SB
SD
SE
XD32020


INDUCTORS (Q ABOVE 1) AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
300
200
100
0
OTHER RANGES
100-μH RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE


CAPACITORS AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
500
400
300
OTHER RANGES
100-μF RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE


INDUCTORS (Q ABOVE 1) AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
300
200
100
0
OTHER RANGES
100-μH RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE


CAPACITORS AT 1kc/s
APPROXIMATE TEST TERMINAL POTENTIAL IN mV
500
400
300
OTHER RANGES
100-μF RANGE
0
20%
40%
60%
80%
100%
"BALANCE" DIAL READING
% OF FULL-SCALE

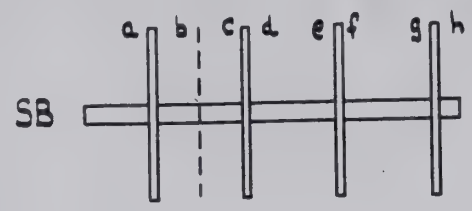


FUNCTIONAL DIAGRAM OF - UNIVERSAL BRIDGE TYPE TF1313

XD 35166

E F G H J K L M

2/2



SEE SHT. 1.

TO MRI -
TO T2 SEC'Y
TO MRI +
TO T2 SEC'Y
TO T2 SCR

H1

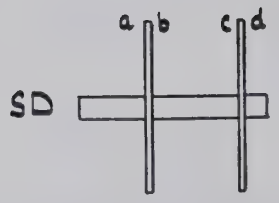
SBd
SBf
SBc

C19 20p TO 120p
C18 0.099
C16 200p
C17 400p
C14 200p
C15 200p
C12 100p
C13 200p

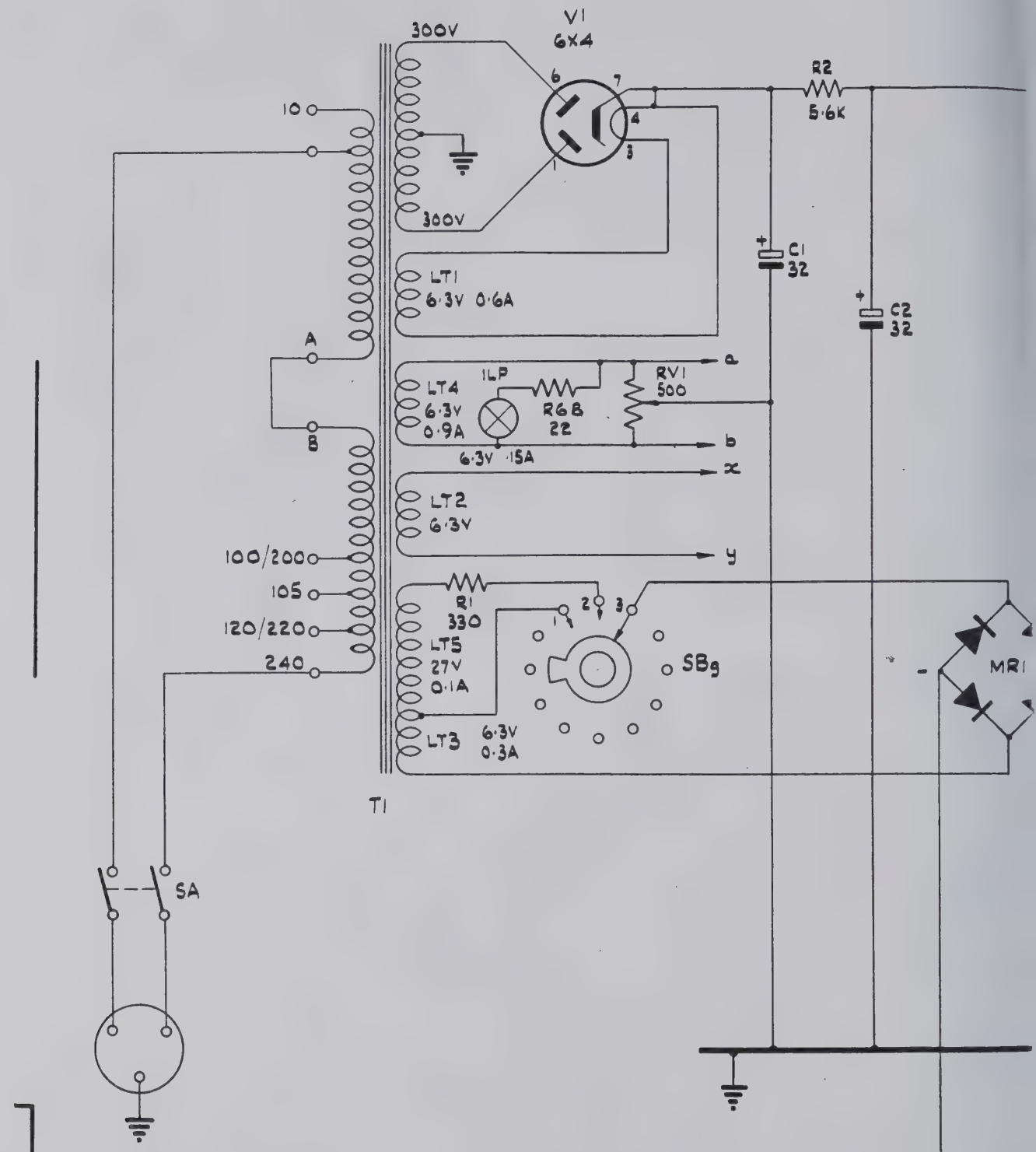
SDb
RV7 51 Q7

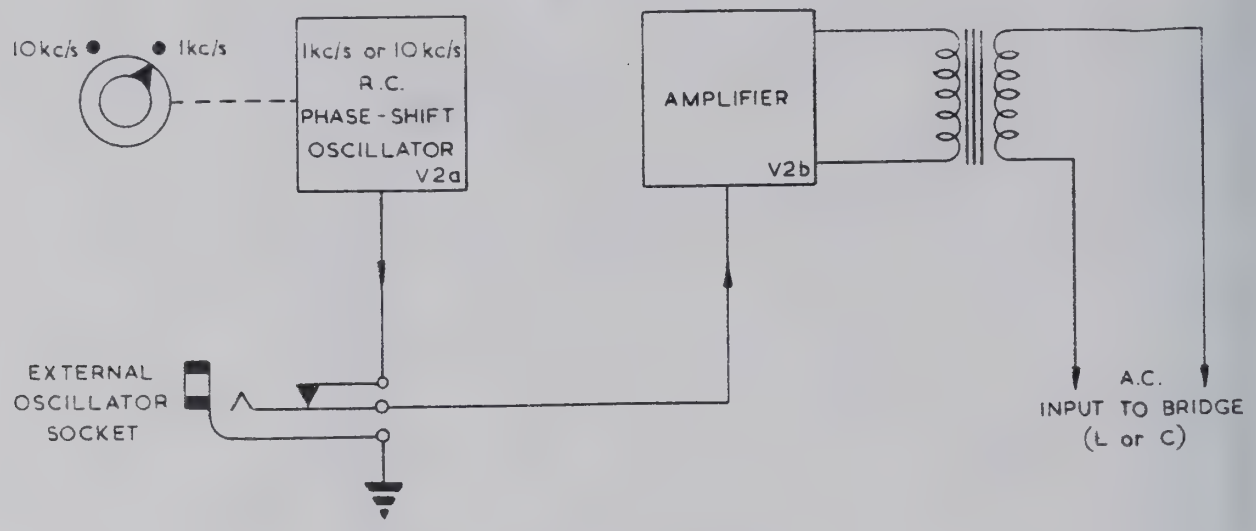
TO C36 SHT. 3

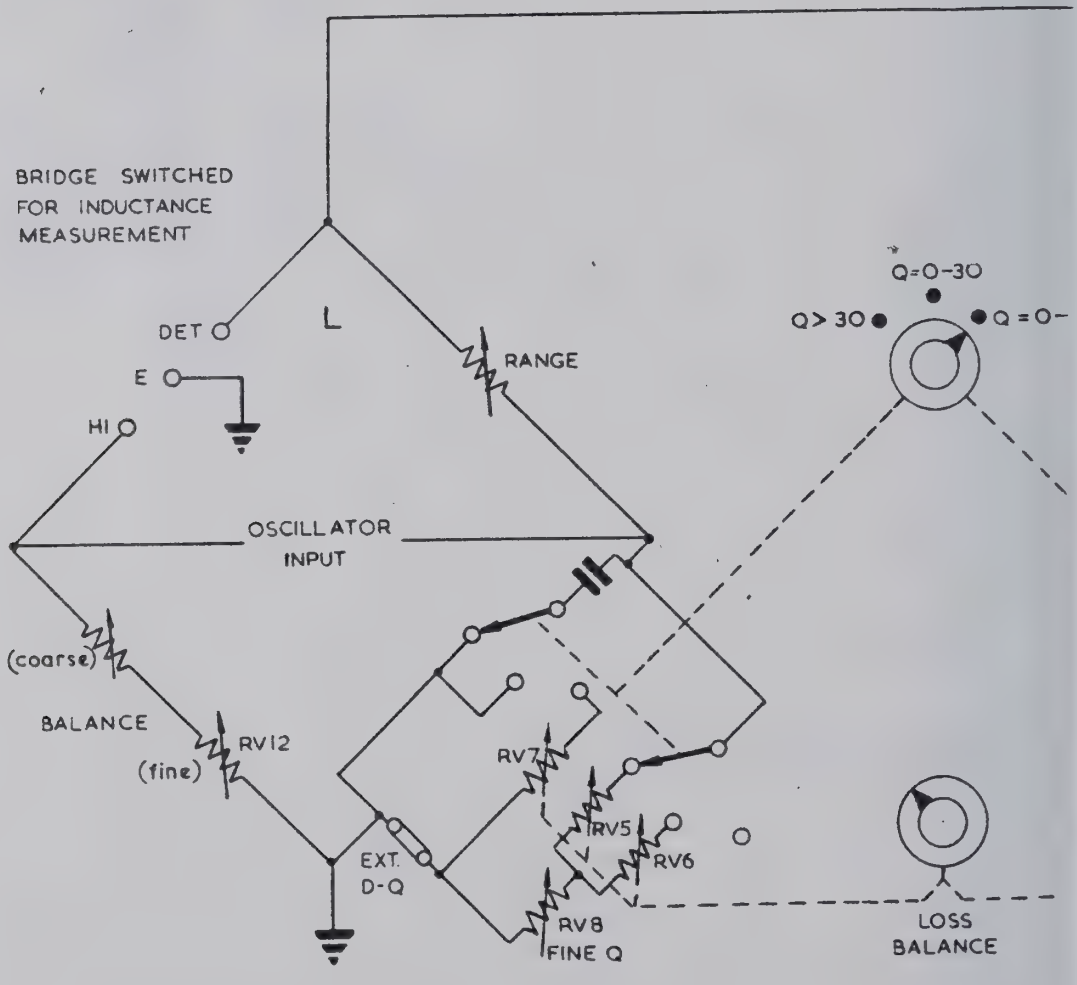
SDd
RV6 51K Q0-30
RV5 5.1K Q0-3
RV8 100 FINE Q



1/2

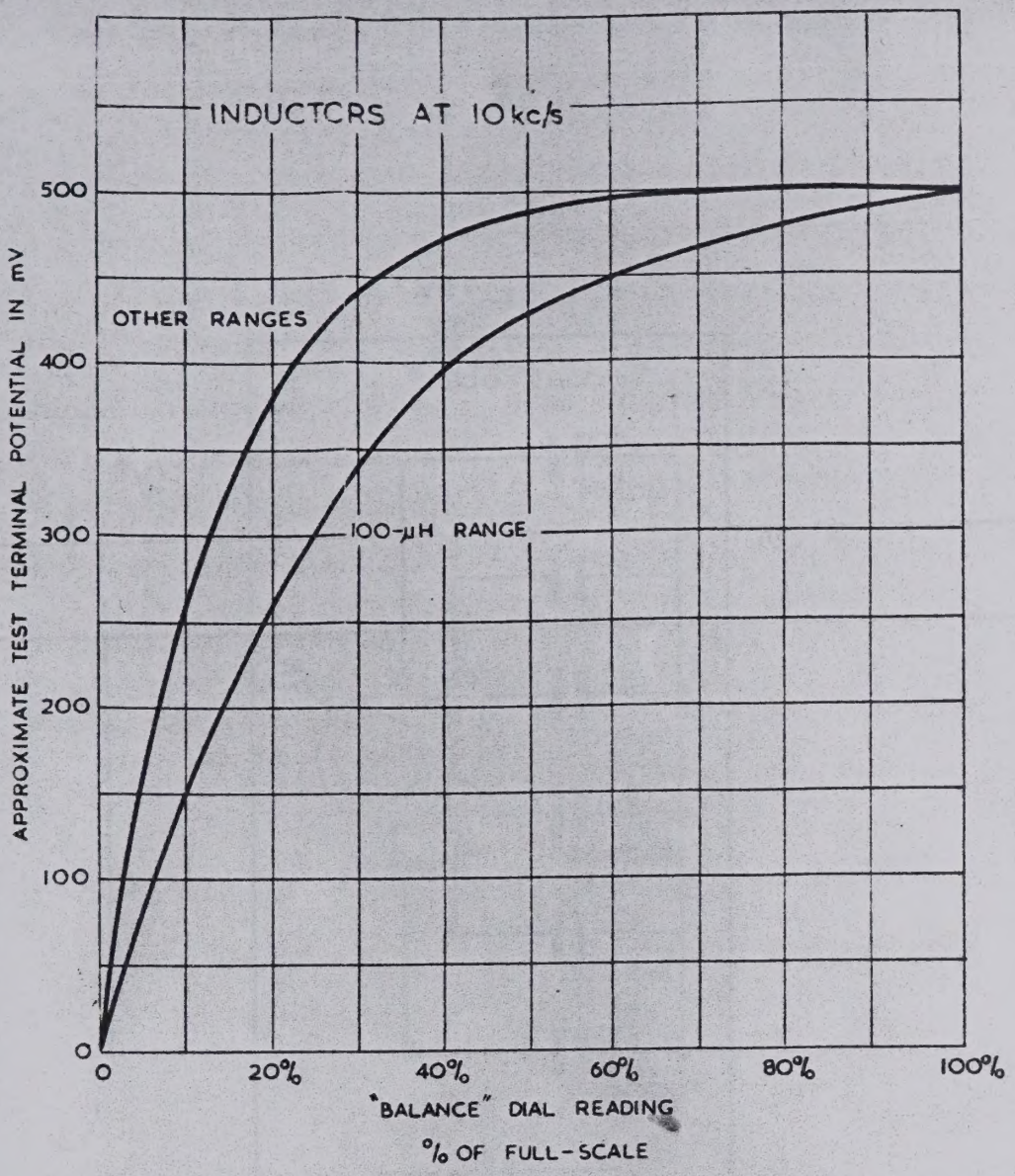

D
E
F
V1
6X4
300V
300V
10
A
B
100/200
105
120/220
240
LT1
6·3V 0·6A
LT4
6·3V
0·9A
1LP
R68
22
RV1
500
a
b
6·3V ·15A
x
LT2
6·3V
y
R1
330
LT5
27V
0·1A
LT3
6·3V
0·3A
SBg
T1
SA
R2
5·6K
C1
32
C2
32
MR1
D
E
F





FUNCTIONAL

1/2



CHARTS OF TEST TERMINAL VOLTAGE AT BALANCE

XD 30557